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AUGUST, 1940

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Treatment of Trichostrongylosis (Black Scour) with Copper Sulphate and Nicotine Sulphate.

*By H. McL. Gordon, B.V.Sc.**

The publication in the last issue of this *Journal* (Gordon and Whitten, 1940†) of the results obtained in a field trial to compare the efficiency of three different treatments in the control of trichostrongylosis in sheep, particularly the high percentage of failures with copper sulphate-nicotine sulphate mixture, has brought a number of inquiries from graziers and others, who have taken it as a general condemnation of this method of treatment—a method they have used for some years and in which they have considerable faith. It is hoped that these notes will explain the real significance of this particular trial and make it quite clear that it was by no means a condemnation of the copper sulphate-nicotine sulphate drench for *general* use in the control of black scour worms.

During the last few years a great deal of work has been carried out, both in Australia and elsewhere, in connexion with the treatment of worms in sheep. Successful treatment in ruminants (sheep, goats, cattle, &c.) presents many difficulties, the first and probably greatest of which is due to the peculiar arrangement of the stomach system in these animals.

The stomach system of ruminants consists of four compartments, the first stomach or paunch (rumen), the second or honeycomb (reticulum), the third or bible (omasum), and the fourth or rennet (abomasum).

It has been found that when water and most of the commonly used drugs are administered in drenches, they have, on the average, about equal chances of being swallowed into the paunch or into the fourth stomach. A few drugs however appear to have a specific effect on the nervous mechanism controlling the swallowing of fluids. Among these, copper compounds, notably copper sulphate (bluestone), has a very pronounced effect on the destination of other drugs given with it or immediately following it. In a large number of experiments its use resulted in the fluids which were swallowed passing direct into the fourth stomach (or abomasum) in 70 to 100 per cent. of sheep (average 88 per cent.) instead of in only 50 per cent. of them.

* An officer of the Council's McMaster Animal Health Laboratory, Sydney.

† Gordon, H. McL., and Whitten, L. K. (1940).—This *Journal* 13: 81–85.

This has an important bearing on treatment for worms, because drugs such as nicotine sulphate, arsenic, and tetrachlorethylene are only effective when they are swallowed into the fourth stomach. Should they be swallowed into the paunch, they become so highly diluted that by the time they reach the parasites further down the gut they are useless. It is therefore evident that the efficiency of drenches such as copper sulphate, or copper sulphate combined with nicotine sulphate, tetrachlorethylene, or arsenic, depends in the first instance on their passage directly to the fourth stomach. When using these drenches one must expect that, on the average, treatment will be unsuccessful in about 12 per cent. of sheep (the proportion in which the drugs are *not* swallowed into the fourth stomach), while on occasions this figure may be as high as 30 per cent.

It was thought that failure of copper sulphate to be swallowed into the abomasum was a matter of chance, and that if treatment was repeated at intervals one would "catch" those individuals which "missed" at previous drenchings. Recently, however, several experiments have shown that certain individual sheep may *repeatedly* fail to swallow copper sulphate into the fourth stomach. Whatever the reason for this, its practical significance is very great. It means that individuals which repeatedly fail to respond to treatment will either die or else live on as a source of reinfestation for other sheep.

These points were demonstrated in the field trial referred to above (Gordon and Whitten, 1940) in which groups of sheep infected with *Trichostrongylus* spp. (small intestinal worms, black scour worms, hair worms) were treated with (*a*) phenothiazine, (*b*) tetrachlorethylene emulsion following copper sulphate, and (*c*) a mixture of copper sulphate and nicotine sulphate. It is proposed to use the results of this trial to illustrate certain points that are of practical significance.

A reduction of 70 per cent. or more in the number of eggs of the parasite in question, per gramme of droppings, was considered to indicate a satisfactory treatment. On this basis, tetrachlorethylene emulsion following copper sulphate was satisfactory in 19 out of 25 sheep (76 per cent.), while the copper sulphate and nicotine sulphate drench was satisfactory in only 5 out of 24 sheep (20.5 per cent.). The excellent results obtained with phenothiazine need not be considered here, since this drug is effective whichever stomach it enters after being swallowed. Other experiments have shown that tetrachlorethylene and the copper sulphate-nicotine sulphate mixture are about equal in efficiency provided they are swallowed into the fourth stomach.

How then can one attempt to explain, firstly, the low degree of efficiency shown by the copper sulphate-nicotine sulphate mixture in this field trial, and secondly, the marked difference in efficiency between this mixture and tetrachlorethylene emulsion following copper sulphate?

The sheep used in the trial were taken from the "tail" of a flock of 10,000 weaners. This flock had suffered a severe outbreak of black scours and the majority of the sheep had been treated eight to ten times each with the copper sulphate-nicotine sulphate mixture. These repeated treatments were successful in over 80 per cent. of the flock, but in spite of them a "tail" of 1,200, that is, 12 per cent., remained seriously

affected. This figure, 12 per cent., agrees with that recorded as the average proportion of sheep in which copper sulphate fails to bring about the changes necessary to ensure that it is swallowed into the fourth stomach. The inference is therefore that it was mainly these sheep which comprised the "tail" mob.

While this explanation appears to be sound, the relatively high efficiency obtained with tetrachlorethylene (depending as it did on the stimulating effect of copper sulphate to encourage its passage to the fourth stomach) seems at first sight to contradict it. There are, however, two possible causes for this seemingly inexplicable difference in efficiency, namely the different concentrations of copper sulphate solutions used and the different methods of administration.

The copper sulphate-nicotine sulphate mixture contained 2 per cent. copper sulphate, while the solution used to precede the tetrachlorethylene emulsion contained 10 per cent. It has been found in South Africa that the passage of fluids to the fourth stomach is more certain the greater the concentration of copper sulphate used; and, further, that sheep in poor condition seldom respond satisfactorily except to high concentrations (10 per cent.). Here then is one of the possible reasons for the greater proportion of successes in the tetrachlorethylene group. The other is that the sheep in this group received the "stimulating" dose of copper sulphate (3 cc. of 10 per cent. solution) *a few seconds before* the tetrachlorethylene emulsion, while sheep in the copper sulphate-nicotine sulphate group received the two drugs as one dose. In the latter instance it was possible for sheep to gulp the dose and swallow it very rapidly, so rapidly in fact that unless the response to the stimulating effect of the copper sulphate was immediate, the whole dose would pass into the paunch before the mechanism which might have directed it into the fourth stomach could operate. The facts that the sheep were in poor condition, and had already almost certainly failed repeatedly to respond to treatment with this mixture on a number of occasions, suggest that their response to copper sulphate was at least sluggish. In the tetrachlorethylene group, however, the few seconds which elapsed between the administration of the stimulating dose of strong copper sulphate solution and the swallowing of the emulsion may well have been sufficient for the operation of the mechanism which directs drenches into the fourth stomach.

It is proposed to carry out experiments further to elucidate these matters as soon as sheep infected with *Trichostrongylus* spp. are available. Meanwhile it should not be concluded that the copper sulphate-nicotine sulphate mixture is useless, but that under certain conditions and in certain sheep it may give comparatively poor results. The immediate practical significance of these results is that in outbreaks of black scours (trichostrongylosis) where two or three repeated treatments with the copper sulphate-nicotine sulphate have failed in a percentage of the sheep, leaving an obvious "tail," it is unlikely that further repetitions of the same treatment will have any better effect. Experiments have shown that phenothiazine is highly effective against *Trichostrongylus* spp. irrespective of whether it is swallowed into the paunch or fourth stomach, but owing to the international situation this drug is not likely to be available in large quantities for some time.

In the meantime, experiments are planned to determine whether or not the "tail" can be dealt with more satisfactorily by copper sulphate-nicotine sulphate mixture if a stimulating dose of concentrated copper sulphate solution is used in advance. Graziers might well try this modification for themselves. No doubt many will try tetrachlorethylene preceded by copper sulphate in spite of its rather high price and the fact that the dose temporarily "knocks out" quite a number of the treated sheep.

Whatever medicinal treatment is given it is essential that the "tail" be separated from the main flock, given the best diet that is economically possible (supplementary feeding, grazing crop, improved pasture) and, what is all too seldom considered, provided with good shelter.

Preliminary Examination of the Anthelmintic Efficiency of Certain Compounds Related to Phenothiazine.

By H. McL. Gordon, B.V.Sc., and M. Lipson, B.Sc.**

Summary.

1. The following compounds related to phenothiazine, namely, phenothiazone, diphenylamine, phenoxthine, phenarsazine chloride, and thionol, have been subjected to preliminary study with the object of detecting anthelmintic properties, toxicity for sheep, and their effect on larval development in faecal cultures from treated sheep.

2. Phenarsazine in doses of 0.04 to 0.12 g. per kg. body weight (1, 2, and 3 g. for sheep of 25 kg. body weight) showed a high degree of efficiency against *Oe. columbianum* but was very toxic for sheep, causing severe inflammation of the rumen and abomasum. Smaller doses were ineffective against *Oe. columbianum* and *H. contortus*.

3. Phenoxthine in doses of 0.25 g. per kg. body weight (10 g. for sheep of 40 kg.) showed a slight degree of anthelmintic efficiency against *H. contortus* and prevented development of larvae in faecal cultures from treated sheep. A dose of 0.5 g. per kg. (20 g. for sheep of 40 kg.) was fatal. Doses of 0.15 g. per kg. were ineffective against *H. contortus*.

4. Phenothiazone (doses of 0.017 and 0.024 g. in water injected into the abomasum of sheep of 25 kg. body weight, and doses by mouth of 0.07 to 0.12 g. per kg. body weight) and thionol (doses of 0.13 g. per kg. body weight) showed no evidence of anthelmintic efficiency against *H. contortus*.

5. Diphenylamine, in doses of 0.03 to 0.12 g. per kg. body weight, showed no anthelmintic efficiency against *H. contortus*. Doses of 0.4 g. per kg. body weight produced temporary reduction in the number of eggs of this parasite in faecal egg counts, development of larvae in faecal cultures was prevented on the day following treatment and only a few larvae developed in cultures prepared on the next two days.

6. None of the compounds tested showed the combination of high efficiency and low toxicity characteristic of phenothiazine which in doses of 0.15 g. per kg. body weight shows a high degree of efficiency against *H. contortus*.

Introduction.

The remarkable anthelmintic properties of phenothiazine have been demonstrated by Harwood, Jerstad, and Swanson (1938), Harwood, Habermann, and Jerstad (1939), Swales (1939), Gordon (1939*a*, 1939*b*, 1939*c*), Gordon and Whitten (1939), and Roberts (1939*a*, 1939*b*).

Phenothiazine is non-toxic for sheep in large doses and has been shown to prevent the development of larvae in faecal cultures made on the four days following its administration to sheep.

The toxicity and insecticidal properties of related compounds have been investigated by a number of workers. Goldsworthy and Green (1939), in studies on certain oxidation derivatives, phenothiazine-sulphoxide, phenothiazone, and thionol, found that the active principle of phenothiazine is phenothiazone, and that this compound is toxic (against apple scab) in dilutions as low as 2.5 parts per million by volume in water. Gersdorff and Claborn (1938) found that of phenothiazine, phenothiazone, phenothiazine-sulphoxide, and thionol, the most toxic for goldfish (*Carassius*) was phenothiazone. McNaught, Beard and De Eds (1939) found that in rats thionol reduced the development of

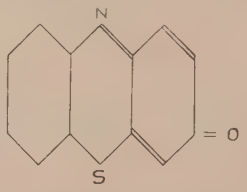
* An officer of the Council's McMaster Animal Health Laboratory, Sydney.

Trichinella spiralis by 55 per cent., while phenothiazine reduced the development by 75 per cent.

In view of these findings, the anthelmintic efficiency of certain compounds related to phenothiazine has been subjected to preliminary study. In addition to including compounds as above, i.e., possessing the same heterocyclic nucleus as phenothiazine, this work has also been extended to other substances in which this heterocyclic nucleus has been altered.

Phenothiazone.

This is an oxidation product of phenothiazine, and a quantity of it was prepared by one of us (M.L.). It is a dark reddish-brown powder, slightly soluble in water and has the structural formula:



Injection of 0.017 and 0.024 g.† dissolved in 30–40 ml. water into the abomasum of sheep of 25 kg. body weight showed no anthelmintic efficiency against *Haemonchus contortus.*

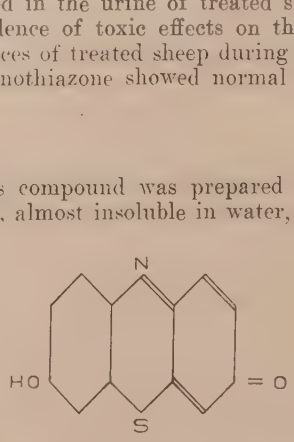
Doses of 3 g. given in capsules and 1.75 g. shaken up in water (0.07–0.12 g. per kg. body weight), following swabbing of the pharynx with a 10 per cent. solution of copper sulphate, also showed no anthelmintic efficiency against this nematode. A reddish-brown coloured compound was excreted in the urine of treated sheep.

There was no evidence of toxic effects on the sheep.

Cultures of the faeces of treated sheep during the five days following administration of phenothiazone showed normal development of larvae of *H. contortus.*

Thionol.

A quantity of this compound was prepared by one of us (M.L.). It is a reddish powder, almost insoluble in water, and has the structural formula:

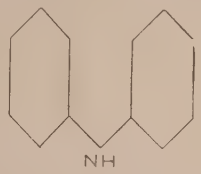


Doses of 4 g. administered shaken up in water were ineffective against *H. contortus* and *Trichostrongylus* spp. There was no evidence of any toxic effect on the sheep. There appeared to be a slight check on the development of larvae in cultures made during the two or three days following administration of this compound.

† g. = grammes.

Diphenylamine.

This is the compound from which phenothiazine is made by heating with sulphur in the presence of a catalyst. It is a colourless crystalline solid, insoluble in water, and has the structural formula:



Doses of 2 and 4 g. in capsules, and 1 and 2 g. shaken up in water (0.03–0.12 g. per kg. body weight) following swabbing of the pharynx with a 10 per cent. solution of copper sulphate, were without anthelmintic effect against *Haemonchus contortus* in sheep. Faecal cultures made during the five days after administration of the above doses of diphenylamine showed normal development of larvae of *H. contortus*.

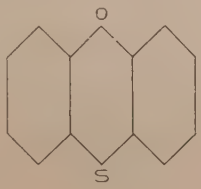
In a further trial, doses of 0.4 g. per kg. body weight were used in three sheep. Doses given were 10.8, 16.0, and 12.8 g., and the drug was administered by shaking up with a wetting agent in water.

Temporary reductions in the number of *H. contortus* eggs per gramme of faeces were observed, and larvae did not develop in cultures prepared on the day following administration of the drug. On the second and third days after treatment, egg counts had increased, and a few larvae developed in cultures prepared from faeces passed on these days. On the fourth day egg counts had returned to pre-treatment levels, and faecal cultures from this day yielded large numbers of larvae. The sheep treated, in addition to moderate infestations with *H. contortus*, carried light infestations with *Trichostrongylus* spp. and *Oesophagostomum columbianum* against which there was no evidence of anthelmintic efficiency.

There was no evidence of toxic effects on the sheep. The urine contained diphenylamine which was recognized by the formation of a characteristic blue colour with oxidizing agents on allowing to stand in the air.

Phenoxthine.

A quantity of this compound was kindly made available by Dr. Adrian Albert, of the Department of Organic Chemistry, University of Sydney. It is a yellow powder, insoluble in water, and having a geranium-like odour. In this compound the imino grouping of phenothiazine has been replaced by an oxygen linkage.

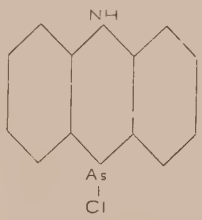


Doses of 0.15 g. per kg. body weight (administered in capsules) were without anthelmintic efficiency against *H. contortus* in sheep. (Doses of phenothiazine of this magnitude are very effective against *H. contortus*.) A dose of 20 g. shaken up in water killed a grown sheep weighing 40 kg. A dose of 10 g. similarly administered to a sheep of similar weight showed no evidence of toxicity and showed a slight anthelmintic effect against *H. contortus* (a 50 per cent. reduction in egg count). There was no evidence of a coloured compound being excreted in the urine.

Faecal cultures made on the second day after treatment showed no development of larvae and exhibited a slight odour of phenoxthine. Cultures made on subsequent days showed normal development of larvae.

Phenarsazine. (Phenarsazine chloride was used.)

A quantity of this compound was kindly made available by Mr. G. Burrows, of the Department of Chemistry, University of Sydney. It is a yellowish powder, insoluble in water and differs in structure from phenothiazine in that the sulphur of the latter has been replaced by arsenic (linked to chlorine in the chloride).



Doses of 1, 2, and 3 g. respectively were given to three sheep in poor condition and weighing about 25 kg. each. The doses were administered, shaken up in water, following a preliminary dose of 5 ml. of 5 per cent. copper sulphate solution.

These doses induced symptoms of gastro-enteritis, the sheep lost their appetites and all would almost certainly have died. The faeces became soft to diarrhoeic in nature and contained large quantities of mucus. These doses removed all the *Oesophagostomum columbianum* harboured by these sheep (112, 55, and 12 worms respectively).

Post-mortem examinations on these sheep made three days, five days, and seven days after administration showed marked inflammatory changes in the rumen and abomasum.

In a second experiment, doses of 0.5, 0.4, 0.3, and 0.2 g. respectively were administered to four sheep in poor condition and weighing about 15–18 kg. each. The sheep which received the larger doses showed loss of appetite and passed soft faeces containing large amounts of mucus. Doses of 0.5 and 0.4 g. removed 134 out of 205 and none out of 9 *Oe. columbianum* respectively. Doses of 0.3 and 0.2 g. did not remove any *Oe. columbianum* from sheep known to be infested with this parasite. Post-mortem examinations were carried out on three of these sheep (those receiving 0.5, 0.4, and 0.3 g.) from 6–7 days after dosing.

No evidence of gastro-enteritis was detected macroscopically, but from the symptoms they had shown it is thought that at least two of these animals would have died.

Doses of 0.25 g., administered shaken up in water, were ineffective against *Haemonchus contortus* and produced transitory loss of appetite. Larvae developed normally in cultures made during the four days following administration of this compound.

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Notes on the Control of Blackberry, Watsonia, Bracken, and Ragwort in Victoria.

*By R. W. Prunster, B.Sc.(Agric.)**

The Noxious Weeds and Vermin Branch of the Victorian Crown Lands Department has for many years conducted investigations into methods for the control of several of the noxious weeds of the State. The methods tried have included spraying with poisons; soil sterilization with materials such as common salt; cultivation treatments and also the sowing of pasture mixtures. Some interesting and valuable results have been obtained from the experiments on the control of blackberry and Watsonia and of bracken and ragwort, and the conclusions are presented in this note.

Blackberry and Watsonia.

At Dandenong (rainfall of 32 inches per annum), 18 miles south-east of Melbourne, 160 acres of cultivable flats had been for years heavily infested with blackberry (*Rubus fruticosa*) and Watsonia (*Watsonia Meriana*). (See Plate 4, Fig. 1.) Arsenical and chlorate sprays were applied with varying frequency during 1936 and subsequent years. While some measure of eradication was evinced by repeated heavy sprayings with poisons, the results obtained do not justify the cost, especially since the land remains unproductive, through soil sterilization.

One of the methods tried was to cut the blackberry and Watsonia top-growth, then to plough the land. Following this a rotary hoe was used to break down the land and to bring the blackberry crowns and the Watsonia corms to the surface, so that after the area was harrowed it was possible to rake the weed material into heaps for burning. The land so treated was then sown with a mixture of perennial ryegrass 10 lb., cocksfoot 5 lb., and white clover 2 lb. per acre, with an application of 90 lb. per acre of superphosphate at seeding. The sowing was unavoidably delayed until June, 1936. From 1936 onward the pasture has been grazed and, when necessary, cut. In November, 1939, the photographs—Plate 4, Figs. 1 and 2—were taken, showing the complete suppression of the weeds by the pasture mixture (Fig. 2); the complete cover of blackberry and Watsonia in untreated areas is shown in Fig. 1. The yield was estimated at over a ton of hay to the acre.

An adjoining area was successfully cleared of these two weeds by similar ploughing, rotary hoeing, harrowing, and the planting of a summer crop (maize) after the corms and the blackberry crowns were raked up and burnt. An excellent crop of maize was grown and the land re-cultivated in the autumn and sown with the pasture mixture of perennial ryegrass, cocksfoot, and white clover. The results were again a complete suppression of the two weeds and an excellent stand of pasture. From these trials it is now justifiable to suggest that where the land is easily cultivable and the rainfall suitable—in excess of 30 inches per annum—both blackberry and Watsonia can be

* An officer of the Division of Plant Industry.

economically dealt with by sowing down to pasture, either after a short summer fallow, or after a summer green crop of maize, sorghum, or millet. Similar success should also be possible by sowing the pasture in the second autumn, a crop of oats being grown in the first year and the stubble ploughed in, in early summer.

It is necessary to emphasize two points. The land must be carefully and thoroughly cultivated; here the rotary hoe is an ideal implement because it brings the regenerating portions of the weeds on or near the surface. Then the pasture mixture should be top-dressed with superphosphate at sowing and annually thereafter. Although only 90 lb. per acre was used in the trials, it is known that even better pasture yields would be possible in these areas with heavier dressings such as a bag, or even 2 cwt. per acre.

Bracken and Ragwort.

In 1937 the settlers of the Toora district in Gippsland requested that experiments be conducted there for the eradication of bracken (*Pteridium aquilinum*) and ragwort (*Senecio Jacobaea*). Fourteen acres of heavily-infested land (Plate 5, Fig. 3), selected by the settlers, were taken over with the sanction of the Closer Settlement Commission, and the area was used for experimental purposes. The land was valued at £1 per acre, the bracken being 4 feet high with a dense stand of ragwort underneath.

The first operation was to cut and burn the bracken. In July, 1937, a mixture of 20 lb. of perennial ryegrass, 10 lb. Akaroa cocksfoot, and 2 lb. of white clover per acre was broadcast on the ash together with 90 lb. per acre of superphosphate.* After sowing the pasture mixture, great care was taken to prevent the bracken regaining a complete hold, by cutting the re-growth three times while the fronds were young. This treatment greatly weakened the bracken; the final cleaning of the steadily thinning stand of new fronds was done by "whipping" with No. 8 fencing wire. It is important to note that the young bracken re-growth was cut or whipped before the fronds opened. Within twelve months a dense sole of pasture was present and the bracken completely beaten. The ragwort re-growth was readily and cheaply controlled by spot treatment with chemical sprays in the spring.

During the past two years the pasture has grown prolifically. In one period of twelve months, 14 bullocks and 100 store sheep were fattened on the 14 acres. In November, 1939, when the photograph (Fig. 4) was taken, the stand of pasture consisted mainly of perennial ryegrass and cocksfoot with a good basal cover of white clover. The yield of hay was estimated as 25 cwt. per acre.

The information gained from these and other trials enables the Noxious Weeds and Vermin Branch to advise the following procedure:—

Where ragwort and bracken occur together, the bracken can be dealt with by cutting and burning, sowing a good pasture mixture of perennial ryegrass, cocksfoot, and white clover on the ash, top-dressing with superphosphate at upwards of a bag per acre, and giving constant attention to keep the bracken in check and to allow the pasture to become well established. The bracken fronds must never be allowed

* Portion of the area was used to test the value of plant poisons in the control of ragwort re-growth. Each chemical tried has given complete success.

to open—therefore frequent cutting or "whipping" must be done. The trial has demonstrated that within twelve months the bracken can be eliminated. In practice, the constant attention required makes it clear that the area to be treated and sown to pasture must be small enough to enable the cutting to be done in time. Too large an area for the labour available will result in failure, because the bracken will spread its fronds and replenish its food reserves in the roots.

The ragwort is easily and simply controlled in the pasture by spot treatment with any one of the following sprays:—

1. Arsenic pentoxide—1 lb. to 5 gal. water.
2. Sodium chlorate—1 lb. to 2 gal. water.
3. Calcium chlorate—1 lb. to 1 gal. water.

Of these, arsenic pentoxide is the cheapest. The spraying should be done in the spring when the plants are in a rosette stage.

The experimental area of 14 acres, valued at £1 per acre in 1937, was sold by public auction in January, 1940, at £10 per acre. These figures indicate that the eradication of weeds and their replacement with valuable pastures is economically possible.

Both at Dandenong and Toora the important principle demonstrated is that if weeds are to be successfully eradicated there are two points requiring attention. The first is that the weeds must be weakened by cutting and burning, as in the case of bracken at Toora, or by ploughing and cultivating as in the case of blackberry and Watsonia at Dandenong. The second is that when the weeds have suffered a severe check it is immediately essential to occupy the land with useful plants—in these instances pasture plants. Finally, the pastures must be generously treated by careful grazing and heavy top-dressing, and if a persistent weed like bracken occurs, successive cutting is necessary for a few months while the pasture is becoming established. Once the land is reclaimed and a good sward of pasture is established, the re-entry of weeds is a sure indication that the pastures are being over-grazed or otherwise mishandled.

Vine Ash in Dipping Sultanas.

*By E. C. Orton, B.Sc., A.I.C.**

Summary.

Experiments have shown that a properly prepared extract of vine ash is suitable for dipping sultanas, and is almost as satisfactory in regard to quality and drying rate as a potash solution of the same density.

1. Introduction.

When the cessation of supplies from overseas made it necessary to conserve potash in Australia, efforts were made to reduce the amount used in dipping sultanas. As potash is obtainable from vine ash, this was used in dipping trials conducted during the past season at the Research Station, Merbein, and elsewhere. Results showed that a properly prepared extract of vine ash for dipping is almost as satisfactory as a potash solution of equal Baumé, in regard to drying rate and quality of fruit.

Samples of ash derived from various portions of the vine have been examined, and it has been found that that obtained from waste fruit has the highest potash content, followed by that obtained from stems and canes, while that derived from the trunk contains the least. Since the quantity of stems and waste fruit available is relatively small, canes (from all varieties) removed during pruning provide the main potential source of potash.

The ash content of sultana canes is roughly 2 per cent., and the average weight of prunings removed per vine is approximately 7 lb. Assuming there are 480 vines per acre, it should be possible to obtain about 67 lb. of ash per acre. If the canes are burned correctly this ash should contain approximately 33⅓ per cent. extractable potash (as estimated by Baumé). Assuming it contains 25 to 33⅓ extractable potash, it should be possible to obtain extract equivalent to 17 to 22 lb. of potash per acre of sultanas. This is more than sufficient to temperature dip the whole of the crop, and should be sufficient to cold dip the major portion of the crop.

2. Method of Burning Canes.

It has been found that the manner in which the canes are burned has a marked effect on the yield of extractable potash. It is essential to burn the canes at as low a temperature as possible in order to reduce the formation of insoluble silicates (clinker) to a minimum. Otherwise an appreciable amount of potash will be lost.

The canes should be raked out and burned in the green or half green condition on a reasonably clean piece of headland, preferably in heaps which are not too large. A certain amount of unburned carbon is not harmful, and it is better to burn incompletely than to use more heat

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than is necessary. When cool, the ash should be bagged and stored. In some cases portable incinerators may be available for burning cuttings. These should prove satisfactory if provided with a suitable tray for retaining ash.

3. Method of Extracting the Ash.

It is necessary to allow ample time for this operation. One satisfactory method is as follows:—

1. Fill a tank (such as an 80-gallon round) about one-third to a half full with ash, and add water until nearly full.

2. Stir thoroughly, allow to stand for an hour or more, stir again, and allow to stand over night.

3. Syphon off the clear liquid by means of a hose.

4. Fill again with water, stir thoroughly, allow to stand until clear, and syphon off again.

5. Repeat this operation until the Baumé of the liquid syphoned off is less than 1 deg. It is usually necessary to extract about three times altogether. The first two extracts can usually be combined and adjusted to the desired Baumé (say 3 deg. Baumé). The last extract, if too weak to be included, should be used in extracting a fresh lot of ash. If desired, the ash can be extracted before the dipping season and the resulting extracts stored in tanks until needed.

With cold dip, 3 deg. Baumé (or higher) is recommended.

With mixed dip, $\frac{3}{4}$ deg. Baumé (plus caustic soda to crack, and oil) should be used.

"Dying Vines" in the Murray Valley.

By D. V. Walters, M.Agr.Sc., and W. V. Ludbrook, B.Agr.Sc., Ph.D.†*

Summary.

1. A trouble known as "dying vines" annually causes the premature death of a small number of irrigated grape vines in the Murray Valley.

2. In most cases, death apparently begins during the dormant period, and the trouble is first noticed when affected vines fail to produce new growth in the following spring.

3. On splitting open the stem of an affected vine, a brown discoloured area, with a characteristic sour odour, is found in the wood at the base of the stem. This usually appears to originate from a tillage injury.

4. An unidentified fungus was isolated from most of the affected vines examined. Healthy vines inoculated with this fungus made normal growth during the following two seasons.

5. It is thought probable that the trouble is primarily physiological.

6. Young vines planted where affected vines died make normal growth, and are apparently no more liable to premature death than are other vines in the same locality.

1. Introduction.

The trouble termed by grape-growers "dying vines" is known to have occurred for over twenty years in the irrigated vineyards of the Murray Valley. According to Mr. D. B. Adam (in correspondence), it has also been found in a vineyard near Adelaide. Usually, the first obvious symptom is the failure of affected vines to make new growth in spring. The vines apparently begin to die during the dormant period. Sometimes water-shoots may sprout from the base, but the new vine formed from these generally dies within a year or two. Less commonly, weak shoots may develop in spring from the previous season's wood, but towards the end of January the foliage wilts before the fruit ripens, and the vine subsequently dies.

Growers reporting losses from this trouble appear usually to have lost from two to five vines per 20-acre holding per annum. The greatest recorded loss on a single property in one season is 30 vines in a 4-acre patch, portion of a 30-acre holding. During 1938, only about 100 affected vines were brought to the writers' notice, in an area of 40,000 acres.

Sometimes the distribution of "dying vines" cannot be correlated with any obvious abnormality of the environment, and they apparently occur at random amongst healthy vines. However, there is some evidence that in other cases they tend to be concentrated in or near depressions in which water lies after irrigation. They occur more frequently on heavy than on sandy soils. These observations suggest that water-logging or salinity may be predisposing factors.

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Most of the affected vines are of the Sultana variety, but this may be due to the fact that between 50 and 70 per cent. of the vines in the areas under observation are of this variety. It is not known whether sultanas are more susceptible than other varieties, e.g., Zante currants, Gordos, Walthams, Ohanez, which are also affected. Sultanas over 50 years old are still producing profitable crops. Vines under eight years of age are not usually affected.

The cause of the trouble is not yet known. It has not been possible to make a detailed pathological examination of affected vines *in situ*; the field observations were made by the senior author, who sent affected vines to Canberra for laboratory examination by the junior author. It is not likely that a closer study of the trouble will be possible at present, and it is, therefore, deemed advisable to publish a summary of the information now available, which indicates that the trouble is probably due mainly to non-parasitic causes, and is not likely to assume serious proportions under normal environmental conditions.

2. Examination of Affected Vines.

As it is not yet possible to identify affected vines from their external appearance before they fail to shoot in spring, detailed observations were necessarily confined to vines that were dying or partially dead for some time before inspection. The following affected vines were examined in the laboratory:—Eight specimens from Merbein, 18–25 years of age; five from the Nyah-Woorinen district, up to 20 years of age and one from a domestic garden in Canberra. They averaged about 3 inches in diameter at the base of the stem. All these vines were uprooted some days before examination, and most of the finer roots were left in the ground. Those that remained on the specimens were more or less dry and shrivelled when received at the laboratory, but appeared normal in other respects.

Each of the thirteen affected vines from the Murray Valley showed one or more deep scars of old tillage injuries, imperfectly callused over, at the base of the stem or on one or more main roots adjacent to the stem. The Canberra vine had forked below ground level, and the fork had split, resulting in an unhealed wound. On splitting the stem of each vine longitudinally, a zone of wood at or near ground level was found to be brown, hard, and dry, with an abrupt borderline between this and the normal, yellowish-white wood of the stem. The affected areas appeared to have spread from the imperfectly healed injuries described above, and usually occupied the whole or nearly the whole cross-section of the stem at ground level, sometimes extending a few inches up the stem, or along a main root, particularly if the latter had suffered a tillage injury. Usually there was unaffected wood both above and below the affected area; the latter had a characteristic sour odour, quite distinct from the faintly sweet smell of healthy wood.

Numerous pieces of discoloured wood from stems and roots, and of apparently normal wood adjoining the discoloured areas, were plated on potato sucrose agar, after surface sterilization with mercuric chloride or calcium hypochlorite. Approximately 30 per cent. of 730 pieces plated yielded an imperfect fungus with scanty, yellowish-brown mycelium and abundant straight, cylindrical, hyaline, one- to three-septate conidia. Various common saprophytes and unidentified

fungi were also isolated, but the first-mentioned fungus was much more abundant in affected wood than any other organism. It was obtained from 12 of the 14 affected vines examined, the two exceptions coming from Woorinen. Attempts to demonstrate fungal hyphae in discoloured wood by staining sections with picro-anilin blue were unsuccessful in most cases, and the wood showed little or no sign of fungal rotting.

3. Inoculation Experiments.

During the autumn and winter of 1938, the following healthy sultana vines were inoculated with the yellowish-brown fungus:— Twelve two-year-old vines in pots at Canberra, 30 vines (17 years of age) at Merbein, and 23 vines (15 years old) at Woorinen. Agar inoculum was introduced, under aseptic conditions, into wounds in the stem just below ground level, which were then plugged with grafting wax or covered with nurseryman's tape. Sterilized inoculum was similarly introduced into an equal number of control vines at each station. All these vines made normal growth in 1938-39 and 1939-40.

Five inoculated and three control vines were examined at Merbein in October, 1938, by shaving off the bark and outer layers of wood near the treated area; one inoculated vine showed a considerable amount of brown staining near the point of inoculation, and the remainder were unaffected. Six inoculated and six control vines in pots at Canberra were uprooted and examined in December, 1939. In both lots, faint brown streaks extended for 0.5 to 3.0 cm. above and below the wounds, which otherwise appeared to be healing normally. The yellowish-brown fungus was isolated from two inoculated vines and one control, but not from the remainder. One inoculated and one control vine, both apparently healthy, were uprooted at Woorinen in February, 1940. Each exhibited the characteristic brown discolouration of the wood, apparently originating from the inoculation wound. The yellowish-brown fungus was isolated from the control, but not from the inoculated vine.

4. Discussion.

As the inoculated vines have now produced two seasons' healthy growth since the date of inoculation, it is probable that the fungus used is only weakly, if at all, pathogenic. Although the inoculated vines should be kept under observation for several more years before drawing final conclusions, the writers are at present of the opinion that the trouble is probably mainly physiological, though slow invasion of the wood, through tillage injuries, by one or more weakly pathogenic fungi may perhaps be a contributory factor.

The trouble termed "non-parasitic apoplexy"* in European vineyards is usually first manifested by wilting and death of the foliage, rather than by failure to produce new growth in spring. It has been ascribed to various unfavourable environmental conditions, but insufficient data are available to determine whether there is any

* Baudys, E.: *Review of Applied Mycology*, 17: 372, 1938.

connexion between the European and Australian troubles. Water-logging, salinity, and over-production may be individually or jointly concerned in the causation of "dying vines," but it is not yet practicable for the writers to investigate these possibilities.

Some of the symptoms of "dying vines," e.g., the sour or fermenting odour and brown discolouration of affected wood, are also characteristic of the disorder of fruit trees termed "sour sap." Dr. B. T. Dickson suggested to the writers that there might be some connexion between these two disorders. "Sour sap" has been attributed to various causes, including pathogenic bacteria and water-logging of the soil.

Owing to close cultivation with horse hoes, tillage injuries are very common on healthy as well as on affected vines in the Murray Valley. This fact, and the isolation of the yellowish-brown fungus from two healthy non-inoculated vines, suggest that wounds and fungal invasion are not primarily responsible for "dying vines." The avoidance of tillage injuries would necessitate increased labour costs for hand hoeing, in excess of any saving which might be effected by a possible reduction in the number of "dying vines." The accepted method of dealing with this trouble is simply to replace the dead vines with new ones, usually by layering a shoot from an adjacent vine, but sometimes with nursery stock. The vines used for replacement are apparently no more liable to premature death than are other vines in the same locality.

Boron Deficiency Symptoms on Pine Seedlings in Water Culture.

*By W. V. Ludbrook, B.Agr.Sc., Ph.D.**

Summary.

1. Young plants of *Pinus radiata* and *P. taeda* were grown in nutrient solutions with and without an adequate supply of boron.

2. Most of the plants grown without sufficient boron developed characteristic symptoms, the chief of which was reduced growth-rate, followed by cessation of apical growth and the appearance of necrotic symptoms at the growing-points of tops and roots.

3. Cessation of apical growth was accompanied by swelling of the stem apex, death of young needles adjacent to the apical bud, and exudation of resin from the bud.

4. The juvenile needles of boron-deficient seedlings were shorter than normal, and developed a bluish-green tint. The mature or fasciculate needles were slower in appearing, fewer, and shorter than those of normal seedlings. There was a tendency towards "fusion" of the fasciculate needles in some of the boron-deficient plants.

1. Introduction.

The experiments here described were made as part of an investigation of the condition known as "needle fusion" of *Pinus* (2, 3). This is a physiological disorder which may cause marked stunting and deformity of affected trees. The needles of each fascicle may fail to

* An officer of the Division of Plant Industry.

separate from one another, and appear as though "fused" together. Trees in this condition gave indications of response to field treatments with boron compounds (3), but these results were inconclusive. The growth of pine seedlings in nutrient solutions with and without an adequate supply of boron was therefore studied.

As far as the writer knows, the only previous report on water-culture studies of boron in relation to conifers is that of Mevius (4). As part of a general investigation of root-growth, he grew *P. pinaster* seedlings for six to seven weeks in triple-distilled water containing amounts of boron (as sodium borate) ranging from 0.01 to 4 mg. per litre, plus 25 to 50 mg. of calcium chloride per litre. He reported that under these circumstances, boron showed no stimulatory effect on the growth of the seedlings. Concentrations ranging from 1:250,000 to 1:20,000,000 produced symptoms of toxicity, viz., yellowing and drying of the needle tips. The lack of stimulatory effect and the toxicity of very low concentrations of borax are possibly attributable to the absence of other salts, except calcium chloride, from the solution.

2. Materials and Methods.

The nutrient solution used in the writer's experiments was one described by Hoagland and Arnon (1, p. 36, solution 1). It was made with once-distilled water from a metal still, and "Analar" reagent chemicals, which were not specially purified. No boron was added to half the cultures, and boric acid equivalent to 0.5 parts of boron per million was added to the remainder. It is not claimed that boron was completely excluded from the boron-deficient cultures. Mn, Zn, Cu, and Mo were included in all the cultures.

The seedlings, started as described below, were grown in one- or two-quart glass preserving jars, covered with light-proof paper. Four seedlings were placed in each jar, this number being decreased to one as they grew larger. They were not all uniform in size at the start of the experiment, but the various sizes were distributed evenly between the plus and minus boron series.

The cultures were kept in a greenhouse for two months, after which they were moved to window-ledges in the laboratory, summer temperatures in the greenhouse being too high for their healthy growth. All solutions were renewed once a week, and were aerated twice weekly except towards the end of the experiments.

It is probable that the growth of some of the pine seedlings was adversely affected by unicellular algae and other organisms which developed in the cultures, and also by the low light-intensity in which the cultures were kept during the summer. A number of the plants died before the completion of the experiments, this mortality and the growth of organisms being unaffected by the presence or absence of boron. However, sufficient plants survived to give definite indications of differences attributable to boron deficiency.

Sunflower, tomato, and maize seedlings grown under similar conditions made excellent growth in nutrient solution with boron, and rapidly developed severe boron deficiency symptoms within one to three weeks of being deprived of this element. The nutrient solution used was possibly better adapted to the needs of these plants than to those of pines.

3. Experimental Data.

(*a*) *P. radiata.*

In June, 1939, *P. radiata* seed was sown on pine humus moistened with nutrient solution, one lot with and one without added boron. No difference was apparent between the two lots on 26th October, when twelve seedlings from each were transferred to jars of nutrient solution, plus or minus boron. Between two and three months later, symptoms attributed to boron deficiency appeared in nine of the twelve "minus boron" seedlings (Pl. 1, Fig. 1). These symptoms, which did not appear in the "plus boron" cultures, are described in Section 4. The other three "minus boron" seedlings died before the deficiency symptoms developed. In six seedlings of each lot, the average measurements on removal from the jars were:—

(1) Height of tops: Plus boron, 10.3 cm.—minus boron, 7.3 cm.
(2) Length of roots: Plus boron, 27.8 cm.—minus boron, 15.7 cm.

The difference between the plus and minus boron series was statistically significant for the roots, but not for the tops.

(*b*) *P. taeda.*

Seedlings grown for two months in soil and then for four months in unwashed river sand were transferred to water culture on 26th October, 1939. Symptoms of boron deficiency appeared about a month later than in *P. radiata*, i.e., three to four months after transfer to nutrient solution. Eight of the twelve "minus boron" seedlings developed the characteristic deficiency symptoms (Pl. 2, Fig. 2), the remainder dying before this occurred. The differences in average measurements of the plus and minus boron seedlings were of the same order as those for *P. radiata*.

An older lot of *P. taeda* plants was also used; these were grown for about fourteen months in the field before transfer to water culture, and were starting their second season's growth at the beginning of the experiment. They were very slow to form new roots in nutrient solution, and many plants failed to survive the transfer. Deficiency symptoms were absent from the first cycle of growth in water-culture, but appeared in the second cycle, about four months after the plants were deprived of boron. Unfortunately, only three plants in boron-deficient solution and three controls survived for this period.

One of the former developed what appeared to be typical "needle fusion" symptoms (2), as shown in Fig. 3. At the time of writing, a month after this photograph was taken, a few of the largest fascicles on the leader were developing normally, but most of those on the leader, and all on the two laterals, were still "fused." One other boron-deficient plant showed marked shortening of the fascicles and exudation of resin from the apical and lateral buds.

Because of the lack of replication, it is uncertain at present whether the "needle fusion" symptoms in the above-mentioned plant are attributable to boron deficiency. "Fusion" of a few fasciculate needles occurred in some of the younger seedlings previously described, but was doubtful or absent in most cases. The writer has never found typical "needle fusion" symptoms occurring naturally in the first season's growth of seedlings in plantation nurseries.

4. Summary of Symptoms Attributed to Boron Deficiency.

The pine plants described above developed the following symptoms when grown in boron-deficient nutrient solution:—

(i) *Reduced Growth-rate of Tops and Roots.*

This was noticeable some time before necrotic symptoms appeared, and was more marked in the roots than in the tops. There was considerable variation between individual seedlings in the intensity of this and other symptoms. This is possibly attributable to differences in the genetic constitution of the individuals used.

(ii) *Cessation of Apical Growth and Appearance of Necrotic Symptoms at the Growing-points.*

(*a*) Cessation of apical growth was accompanied by swelling of the stem apex, death of young needles adjacent to the apical bud, and exudation of resin from this bud. Occasionally, several weak lateral shoots developed just below the apex.

(*b*) Marked swelling and grey discolouration of the root-tips occurred (Fig. 1). Longitudinal growth of affected root-tips ceased.

(iii) *Foliage Symptoms.*

The juvenile (non-fasciculate) needles were shorter than those of plants supplied with boron (Fig. 1), and developed a bluish-green tint, contrasting with the greyish-green colour of normal juvenile needles. The mature or fasciculate needles were slower in appearing, fewer in number, and shorter in boron-deficient than in normal seedlings (Fig. 2). In a few plants there was a tendency for the fasciculate needles to be "fused" (2) but this was not sufficiently marked or constant to be regarded as significant at present.

None of the above symptoms appeared in plants receiving an adequate amount of boron.

5. Discussion and Conclusion.

The above results are thought to demonstrate the necessity of boron for the normal growth of *P. radiata* and *P. taeda* in water culture. It is recognized that the experiments here reported are unsatisfactory in some respects, but in view of the length of time which must elapse before confirmatory results can be obtained, and the practical interest of the results, it is thought that their description at this stage is justified. Further experiments are desirable.

The most important symptom described, viz., necrosis of the growing-points of stem and roots, is characteristic of boron deficiency in other plants. It is unusual, however, for boron deficiency symptoms to develop so slowly. The explanation may be that a minute amount of boron was present in the culture-solution, enough to support the slow growth made while the plants were establishing themselves, but inadequate for the faster subsequent growth.

No claim is made that "needle fusion" symptoms, as they occur in pine plantations, are caused by boron deficiency. At present, evidence from field experiments does not favour this view (3, 5). It

may be found that the symptom termed "fusion" of the needles can be produced by more than one cause. In view of the marked effect of boron deficiency on the growing-points of the roots, it appears possible that mycorrhizal development, which is dependent on active root-growth, may be affected by deficiency of boron in plantation soils.

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ADDITIONAL NOTE.

In a continuation of the paper by H. E. Young (*Qld. Agric. J.* 53: 434-453, 1940), it is suggested that "needle fusion" symptoms may result from a deficiency of carbohydrates, which is normally made good by mycorrhizal activity; in Part IV of the same paper it is suggested that the temporary beneficial effect of boron compounds on "needle fusion" trees may be due to their stimulation of chlorophyll formation. If this hypothesis is correct, the explanation of the writer's results with boron in water culture may possibly be of a similar nature. Pine seedlings grown in mineral nutrient solution would be entirely dependent on photosynthetic activity for their supply of carbohydrates, the inadequacy of which may have been responsible for their poor growth and tendency to develop "needle fusion" symptoms. Assuming this to be so, the beneficial effect of boron on pine seedlings in nutrient solution may then be attributable at least in part to stimulation of chlorophyll formation and increased carbohydrate synthesis. —W.V.L.

Observations and Experiments on Diplodia Die-Back of Pines at Canberra, A.C.T.

By W. V. Ludbrook, B.Agr.Sc., Ph.D., and N. H. White, B.Sc.**

Summary.

1. *Diplodia pinea* has been observed in association with die-back of pine trees at Canberra during the past six seasons.

2. In one group of *Pinus ponderosa*, *Diplodia* die-back of scattered shoots appeared each season, but the fungus usually failed to pass the first or second node below the point of infection. These localized attacks did not seriously affect the general growth of the trees during the period of observation.

3. It is probable that the death of numerous trees in other stands of several species of *Pinus* was caused primarily by unfavorable environmental conditions, e.g., excessive competition for soil moisture, attack by *D. pinea* being secondary.

4. Of 99 wound-inoculations with *D. pinea* on 6 species of *Pinus*, 37 gave positive results. Surface (unwounded) inoculation of *P. radiata* was successful in 2 out of 15 attempts.

5. In all but 6 of the effective inoculations, die-back was apparently checked at the first or second internode below the point of inoculation. The exceptions were all inoculations on weak lower laterals.

6. The writers' experiments indicate that under Canberra conditions, *D. pinea* is not likely to cause serious injury to the species of *Pinus* studied unless there are predisposing factors.

1. Introduction.

The fungus *Diplodia pinea* (Desm.) Kickx (also termed *Botryodiplodia pinea* (Desm.) Petr., *Sphaeropsis ellisi* Sacc., &c.) occurs very commonly in association with die-back and other diseased conditions of pines (1, 3, 7, 8). It is ubiquitous as a saprophyte on debris in pine forests. Some authors consider it incapable of causing serious injury to pines in the absence of predisposing factors, e.g., drought, unfavorable soil conditions, or attempts to grow species outside their natural environmental range (1, 4, 6). Occasionally, however, it has been observed in circumstances suggesting more active parasitism (2, 5). The object of this paper is to report local observations and inoculation experiments tending to support the former view.

2. Field Observations.

Pines attacked by *D. pinea* have been under observation at Canberra since 1934, when die-back of leaders or scattered laterals was seen on several trees in two small ornamental groups of *Pinus ponderosa* Dougl. adjoining the Australian Forestry School. These trees were then from 6 to 16 years old. The attention of one of us (W.V.L.) was directed to them in 1934 by Mr. C. E. Lane Poole, Inspector-General of Forests.

Every year since then a few of the growing-points have been killed, apparently as a result of *Diplodia* infection, but in most affected branches or leaders the fungal invasion was checked at the first or second node on the adaxial side of the point of infection. Dead leaders were superseded by adjacent laterals. About twenty trees were affected. In one of the oldest, several branches died back to the trunk, but the tree as a whole was still vigorous at the time of writing. In the

* An officer of the Division of Plant Industry.

remainder, the trouble was of little or no consequence, except for the unsightly appearance of dead foliage on the few affected twigs, during the six seasons since it was first observed.

During the same period, numerous trees died in other plantations within a mile of the Forestry School. These were mostly *P. radiata* D. Don, 20 to 25 years old, but included several other species. The early symptoms often resembled those of *Diplodia* die-back, and the pycnidia of this fungus developed on the dead wood. Most of the deaths occurred in stands of *P. radiata* which were apparently too crowded for local conditions. In Canberra, hot, dry, westerly winds often prevail during the summer, resulting in periods of high saturation deficit, and it is probable that the deaths were merely a form of natural thinning induced by competition for soil moisture. This view is supported by the fact that trees in the outermost one or two rows of a block usually remained healthy. These "break trees" were subject to much less root-competition than others further inside the block. *D. pinea* possibly hastened the death of some of the affected trees, but there was no evidence that it was the primary cause of the mortality.

However, several large isolated ornamental specimens of *P. ponderosa* in the Yarralumla Nursery were also severely affected. These were about 20 years old. The early symptoms resembled those attributed to *D. pinea* in the *P. ponderosa* adjoining the Forestry School, but die-back became so extensive in two of the former trees that they were not considered worth preserving. They were accordingly felled and cut up for examination. The wood of the roots and trunk appeared normal, signs of fungal attack being found only in wood which had apparently been dead for some time. Many of the branches and under parts of the leaders were in this condition; pycnidia of *D. pinea* were present on the dead bark.

The Yarralumla Nursery trees were not subject to intense competition for soil moisture. Two of them were artificially watered during one summer, after severe die-back had already occurred, but they failed to respond to this treatment. It appears possible that *D. pinea* may have functioned as an active pathogen on these trees. The cause of their special susceptibility to die-back is still uncertain.

3. Inoculation Experiments.

In order to determine to what extent *D. pinea* is likely to be responsible for this trouble under local conditions, inoculation experiments, of which the results are summarized in Table 1, were made. Agar cultures of isolates from several different sources were used as inoculum. The point of inoculation varied from 3 to 18 inches below the growing-point of a leader or later shoot. Moist chambers were not used, but the areas inoculated or used as controls were covered with damp cotton-wool and tinfoil or waxed paper for about ten days after treatment. Fifteen inoculations of *P. radiata* were made in February, and the remainder between the 14th and 18th March, 1938.

Most of the treated trees were kept under observation until the growth of the second season after the date of inoculation was well advanced. Re-isolations were made from a number of inoculated shoots. Of 94 controls, 90 remained healthy and 4 weak lower laterals died; the suppressing effect of overhanging foliage was probably at least a contributory factor in the death of these shoots.

When inoculation was effective, the portion of the shoot on the distal side of the point of inoculation usually died within a month. On most of these shoots, the infection was checked at the first or second node below the point of inoculation, and there was no visible extension of the diseased area during the nine months before the time of writing. The six exceptions, in which more extensive die-back occurred, were inoculations made on weak lower laterals, the greater susceptibility of which was possibly caused by the suppressing effect of overhanging foliage.

ABLE 1.—RESULTS OF INOCULATING SPECIES OF *Pinus* WITH *Diplodia pinea*.*

Species.	Approximate Age in Years.	Type of Growth.	Locality.	Leaders.		Laterals.		Number of Laterals in which Die-back was not checked before passing 2 Nodes.
				Number Inoculated.	Number Developing Die-back.	Number Inoculated.	Number Developing Die-back.	
caribea ..	5	Moderately vigorous	Black Mountain ..	5	1	5	1	0
muricata ..	5	Crowded, weak ..	Black Mountain ..	5	5	5	3	3
muricata ..	20	Stunted ..	Forestry School ..	..	..	5	2	0
pinaster ..	5	Crowded, weak ..	Black Mountain ..	5	0	5	0	0
ponderosa ..	4	Vigorous ..	Black Mountain ..	5	0	5	5	0
ponderosa ..	10	Vigorous ..	Forestry School ..	..	..	10	3	1
radiata ..	8	Vigorous ..	Black Mountain ..	5	0	15	11	1
radiata ..	20	Vigorous ..	Forestry School ..	..	..	5	0	0
radiata ..	2 to 3	Vigorous ..	Greenhouse (Potted)	9	4	5†	2	0
radiata ..	4	Vigorous ..	Black Mountain ..	10†	0	..	..	0
taeda ..	5	Moderately vigorous	Black Mountain ..	5	1	5	1	1
Total for all species	.. ..	.. .. ..	.. .. ..	49	11	65	28	6

* Wound inoculations of field-grown trees, except where otherwise specified.
† Surface inoculations of young unwounded shoots.

4. Discussion of Field Observations and Results of Inoculation Experiments.

Although *D. pinea* is undoubtedly capable of actively parasitizing limited portions of vigorous trees, the writers' observations and experiments suggest that such trees are normally able to resist its advance, and to confine the damage to relatively insignificant amounts. If the trees are so affected by predisposing factors that they cannot check the progress of the fungus, extensive die-back or death may follow.

The resistance of an affected shoot or tree appears to be correlated with its vegetative vigour. During the summer of 1934-35, severe hail-injury to a plantation at Penrose, N.S.W., was followed by very numerous deaths from *Diplodia* die-back in stands of *P. radiata* from 12 to 14 years old. Being on very poor soil, these were in a weak and stagnating condition. Young and vigorous trees, equally affected by the hail, showed no sign of fungal attack, and suffered no serious check in their growth.

With regard to the writers' inoculation experiments, it is realized that more extensive die-back might have resulted from inoculations made at other times of the year or on older trees. It would be desirable to test this hypothesis by inoculations in spring or early summer, including trees over 20 years of age, but this has not been practicable. However, the rapidity with which affected shoots died suggested that conditions at the time of inoculation favoured quick development of the fungus in the tissues. Moreover, the results of the inoculation experiments were supported by the observations of natural infections on the *P. ponderosa* adjoining the Forestry School.

The experimental evidence suggests that under the conditions prevailing in the Australian Capital Territory, *D. pinea* is not likely to cause serious injury to the species of *Pinus* studied, unless it is assisted by predisposing factors, such as excessive competition for soil moisture in overstocked stands. However, there are indications that the susceptibility of *P. ponderosa* to *D. pinea* increases with advancing age.

5. The Fungus.

No conspicuous differences were noted between isolates from different sources, except that one obtained from Broadwater pine plantation, near Eden (N.S.W.), formed pycnidia more freely in culture than did the others. As it resembled *D. natalensis* Pole-Evans in this respect, its pathogenicity to lemon fruit was compared with that of *D. natalensis* and *D. pinea,* by wound inoculation. *D. pinea* produced very small localized lesions, *D. natalensis* produced rapid and extensive rotting, and the Broadwater isolate, though distinctly more pathogenic to lemons than the typical *D. pinea,* was very much less so than *D. natalensis,* and lacked the striations on the spores characteristic of the latter species (8). It is, therefore, regarded as merely a variant of *D. pinea.*

6. Acknowledgments.

The writers wish to acknowledge the assistance of Miss M. Blackwood in making the February series of inoculations, and of Mr. H. E. Young in supplying cultures of *Diplodia* species for comparison with the local isolates. They are also indebted to members of the Australian Forestry School staff for advice and criticism.

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A Preliminary Study of the Chemical Retting of Linen Flax.

By A. M. Munro, M.A. (Oxon).

Summary.

Some of the advantages which would be offered by chemical processes for the retting of linen flax are explained and a comparison made between the usual bacterial method of retting and chemical treatments. The physical properties and appearance essential to a chemically retted fibre are described. An outline is given of the nature of the chemical retting problem and reference is made to chemical analyses and investigations into the changes which occur in the flax straw and fibre during bacterial and chemical retting respectively. Examples of chemical rets are given and it is pointed out that the usual methods for determining the end point of a ret are not applicable. In conclusion, laboratory retting plant and the probable cost of chemical processes are referred to.

1. Introduction.

The bacterial retting of flax, during which the flax straw is steeped for some days in warm water, under carefully controlled conditions of temperature and dilution, has already been described in this *Journal* (1), but during recent months chemical methods for the retting of flax have received considerable attention and a preliminary outline of this subject is now submitted. Research on chemical retting has been undertaken because it is considered that chemical as opposed to bacterial processes for the preparation of the fibre from flax straw offer many notable features. Among the more obvious advantages of a chemical treatment the following may be cited:—

(1) There is the definite possibility of a more accurate control of the retting operation than is practical in the case of bacterial processes, the latter being dependent on many accidental and uncontrollable factors such as the original bacterial content of the straw, the cleanliness or otherwise of the retting tanks, and seasonal variations in the quality of the water employed.

(2) The opportunity afforded, by the operation of this control, of preparing fibre, from different rets, of a more uniform quality than is possible in the case of warm water tank retting.

(3) The avoidance of over or under retting with a greater measure of accuracy than is possible when making use of the less controllable retting bacteria.

(4) The securing of a higher yield of long line fibre and tow and of a higher line-tow ratio through accurate retting.

(5) The securing of a greatly increased output of fibre from a given plant and capital expenditure through time saving; a chemical ret may occupy eight hours as compared with the 120–160 hours required for a bacterial ret.

(6) The avoidance of objectionable, evil-smelling effluents, the disposal of which in the case of tank retting is a serious problem.

(7) The probability, through the operation of accurate control, of being able to prepare a stronger and more valuable fibre than can be made consistently when tank retting.

(8) The likelihood, through the employment of comparatively powerful and penetrating chemical reagents, of being able to impart an even degree of ret to samples of flax straw varying in thickness, maturity, and other physical qualities. Different straws ret at varying rates during the bacterial process.

2. Essentials in Chemical Retting.

In connexion with chemical retting, certain considerations with regard to the quality of the resulting fibre are of the utmost importance. In past years certain processes have been developed which had for their object merely the separation of a fibre from flax straw; they could not be called true chemical retting methods. The fibre separated by chemical means must not be just a fibre; it must be a material closely resembling, both in physical properties and appearance, the better grades of flax fibre produced by bacterial retting. It must have strength, softness, fineness of division, resistance to abrasion, resistance to moisture and "weathering," the ability of being spread and spun into yarn on standard flax machinery, the right degree of elasticity and apparent density, and lastly a pleasing colour, gloss, and general appearance. Like many other raw materials flax fibre is evaluated partly on general appearance, and if the appearance of chemically retted fibre were unusual or poor such fibre would not be acceptable.

A severe limitation to chemical retting methods is set by the question of cost. Owing to the bulky nature of flax straw large volumes of water must be used for bacterial rets. Six thousand gallons of water for 1 ton of flax straw is often necessary. Similarly in the case of chemical rets a similar volume of chemical solution is necessary. It becomes evident that only low-priced chemicals, in low concentration, can be employed from an economic view-point. Fortunately weak acids, alkalies, and soaps have been found to be useful for the chemical process.

3. The Nature of the Problem.

In the case of bacterial retting it has been loosely stated that during the retting process the bacteria destroy or partly destroy the cementing substances or pectins which hold the fibres to the cortex and to the woody core of the flax straw. In other words the bacteria during their life cycle exert a selective biochemical action on the vegetable cells of the straw, which results in the fibres being loosened to such a degree that when the straw is dried and "scutched" or beaten, the wood or "shive" can be more or less completely separated from the fibres. In the literature this very broad statement that the "pectin substances are destroyed during the retting process" still persists, and apparently no attempts have been made hitherto to determine exactly what chemical changes occur. For an intelligent attack on the problem of chemical retting it is necessary to know something of the chemical changes which occur in the straw and fibre both during bacterial and chemical retting, and to ascertain whether the two processes are similar or at least bear some resemblance to each other. A beginning has been made with this work (2).

The losses which occur in the chemical constituents of flax straw during bacterial retting were first of all determined. After this work had been completed, the losses during bacterial retting were re-determined and at the same time compared with those occurring during certain chemical rets and during the separate stages of these rets. This procedure both gave an indication of the materials which a chemical ret must remove in order to give a retted fibre and also proved that the changes taking place during bacterial retting and those chemical processes investigated were remarkably similar. Chemically retted fibre, which differs very little in its chemical analysis from bacterially retted fibre, can be produced (3).

It appears from the foregoing work that, provided some knowledge is obtained of the chemical changes taking place in the flax straw and fibre during warm water tank retting, the devising of chemical methods for attaining the same result offers no insuperable difficulty. Technical details in the chemical processes so far discovered are mainly concerned with the development of methods which will yield a spinnable fibre of the required physical properties.

4. Examples of Chemical Retting.

Many of the early experiments in chemical retting were concerned with the search for low-priced chemical reagents which would, in a reasonable time, bring about reactions resulting in the separation of a suitable fibre. Among those found to be useful may be mentioned hydrochloric acid, sulphuric acid, sodium hydroxide, sodium carbonate (soda ash), oxalic acid, ammonium hydroxide, and oleic acid. These materials were usually employed in concentrations varying from tenth to fiftieth normal and at temperatures of from 60°-100°C. The general plan employed was to give the flax straw an acid treatment and then follow with an alkaline treatment. No other oil, fatty acid, or soap has so far been discovered which will replace oleic acid, although a large number have been tried. Speaking in a general way the following conclusions were arrived at:—

Acid followed by alkaline treatment, without oleic acid, yields a harsh fibre. Oleic acid, employed with excess of sodium hydroxide, appears to both hasten the ret and give a softer fibre more closely resembling bacterially retted fibre. Oxalic acid has a bleaching effect on the resulting fibre but may be useful in suitable concentrations.

The following procedure is a typical example of a chemical ret:—

First Treatment.—Boil the flax straw for 6 hours in N/50 hydrochloric acid using a ratio of straw: water of 1:15.

Second Treatment.—Boil the treated flax straw with N/50 sodium hydroxide to which has been added 0.125 per cent. of oleic acid (measured as a percentage of the liquid) using a straw: water ratio of 1:15.

Without attempting a full explanation, at this stage, of the chemical changes which occur, it may be surmised that hydrolysis of certain cementing substances occurs, solution of some materials, and, through the emulsifying action of sodium oleate, suspension and ultimate removal of certain constituents (3). Oleic acid or sodium oleate also

probably replaces natural wax removed during the reactions and gives the necessary oiliness to the finished fibre. It appears that the action of oleic acid in this ret is specific, and no other oils or fatty acids have yet been discovered which will replace it.

With regard to the determination of the end point of a chemical ret, that is, the stage at which the ret has proceeded far enough to yield a suitable fibre from a technical point of view, the usual physical tests on the wet straw have been found to be not altogether reliable; there is a tendency for the chemically treated material, especially when oleic acid is present, to appear from these physical tests more retted than it actually is, and experience is necessary to allow for this. Electrometric titrations, successfully employed for end point determinations in bacterial rets, while affording useful indications of the acidity or alkalinity have not so far been adapted for end point determination in chemical rets.

5. Laboratory Retting Plant.

Lead lined tanks, with steam heating coils, have been found to be very satisfactory for the performance of chemical rets. Where temperatures below boiling point are required, hand operation of the steam valves is practicable, although electrical heating has also been successfully applied. An advantage of working at 100°C. is that by keeping the solutions slowly boiling agitation of the liquors is assured. On a small scale the straw is taken out of one chemical bath and placed in another as required, but on large scale working it would of course be more economical to allow the straw to remain in the tanks until the end of the process and change the liquors.

6. Possible Cost of Chemical Retting Processes.

The cost of a chemical retting process can never be as low as that of the bacterial one where plain water is used at lower temperatures than those employed in a chemical ret. The use of the shive from the retted straw will supply all the heat necessary for chemical retting, and the chemicals required might amount to about £2 per ton of original straw. This extra cost will, however, be undoubtedly compensated for by the many advantages possessed by a chemically retted fibre and by the increased output from a given plant, as described in the introduction.

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An Examination of the Chemical Differences Between Chemically and Bacterially Retted Flax Straw and Fibre.

*By Jean F. Couchman, B.Sc.**

Summary.

Flax straw can be retted by chemical means, using two successive boiling treatments, to produce a fibre whose chemical analysis is remarkably similar to that of fibre obtained from a bacterial ret.

The respective retting losses of the bacterially and chemically retted straws are undoubtedly of the same order throughout.

Owing to the extent of the hydrolysis caused by the first boiling treatment (viz., with N/50 hydrochloric acid), it has been surmised that this treatment is necessary for the production of a successful chemically retted fibre.

In order to prevent the diminution of the oil content of the fibre during the chemical retting, it is necessary to add small amounts of oleic acid to the liquor in the second boiling treatment.

The most essential chemical difference, apart from the oil content, between the chemically and bacterially retted fibres has been shown to be the higher lignin content of the former which is closely related to the extractable material. The presence of oleic acid appears to have a tendency to keep this figure down.

Sodium carbonate is equally as effective as sodium hydroxide when used as a retting agent in conjunction with oleic acid in the second treatment.

I. Introduction.

As the chemical retting of flax straw had reached the stage where it appeared to be promising from both an economical and a practical point of view, the determination of small differences which were apparent between the composition of the chemically and bacterially retted fibres was considered to be desirable.

The most successful chemical retting up to date was obtained by Munro (1), using the following two treatments:—

First Treatment.—Boiling for six hours with N/50 hydrochloric acid, using a ratio of straw/water = 1/15.

Second Treatment.—Boiling for six hours with N/50 sodium hydroxide to which had been added 0.125 per cent. oleic acid (measured as percentage on volume of liquid) using the same ratio of straw/water.

In addition to this ret, the use of sodium carbonate instead of sodium hydroxide in the second treatment appeared to be quite promising.

From a survey of all the preliminary work carried out by Munro (1), it was decided that the following information was necessary for the improvement of chemically retted fibre:—

(i) The determination of any essential chemical differences which might exist between chemically and bacterially retted flax straw and fibre.

(ii) A comparison of the retting losses incurred by the bacterially and chemically retted straws.

* An officer of the Division of Forest Products.

(iii) The part played by the first treatment (viz., boiling with N/50 HCl) in the retting treatment.

(iv) The effect on the retting of the use of oleic acid in the second treatment.

(v) A comparison of the relative merits of sodium hydroxide and sodium carbonate used as retting agents in the second treatment.

As a result of a series of experiments designed to yield information on these five points, analyses of the following materials were obtained :—

Sample No.	Materials Analysed.	Retting Treatment.
1	Unretted straw	
2	Bacterially retted straw and fibre	Warm water tank ret at 33°C. (2), the end point being determined by the electrometric method (2)
3	Acid treated straw	Boiling for six hours with N/50 hydrochloric acid using a ratio straw/water = 1/17
4	Chemically retted straw and fibre	*1st Treatment.*—Boiling for six hours with N/50 hydrochloric acid, using a ratio straw/water = 1/15 *2nd Treatment.*—Boiling for six hours with N/50 sodium hydroxide + 0·125 per cent. oleic acid, ratio straw/water = 1/15
5	Chemically retted straw and fibre	*1st Treatment.*—Boiling for six hours with N/50 hydrochloric acid, ratio straw/water = 1/17 *2nd Treatment.*—Boiling for six hours with N/50 sodium hydroxide + 0·21 per cent. oleic acid, straw/water = 1/17
6	Chemically retted straw and fibre	Similar to No. 5, but without any oleic acid in the 2nd treatment.
7	Chemically retted straw and fibre	*1st Treatment.*—Boiling for six hours with N/50 hydrochloric acid, straw/water = 1/17 *2nd Treatment.*—Boiling for six hours with N/30 sodium carbonate + 0·21 per cent. oleic acid, straw/water = 1/17
8	Chemically retted straw and fibre	Similar to No. 7, but without any oleic acid added in the 2nd treatment

N.B. The oleic acid is expressed as percentage by volume on the volume of liquid.

Good quality reaped de-seeded straw from the 1937 crop at Colac, Victoria, which had been well blended to ensure uniformity, was used for all the above treatments.

In order to simplify the presentation of the results, the straw analyses have been set out in tables separate from those showing the corresponding fibre analyses throughout.

2. Methods of Analysis.

Except in the following instances, the methods used were identical with those set out in a previous publication (3).

(i) *Preparation of Fibre Samples for Analysis.*

The fibre samples were cut into approximately ½-in. lengths and ground in a Wiley mill using the two-millimetre screen. The ground samples were well mixed by hand to ensure uniform sampling.

(ii) *Solvent Extraction of Fibre Samples.*

As the fibre samples yielded no material soluble in benzene-alcohol or alcohol, all the samples examined were extracted with ether only.

(iii) *Cellulose* (Cross and Bevan).

For the first two fibre samples, the cellulose was determined on both the totally extracted and solvent extracted samples. After examination of these results it was decided that for the remaining fibre samples analysis of the solvent extracted samples would yield sufficient information for all practical purposes. A chlorine water method, standardized in this Division (unpublished work) from the procedure described by Benjamin and Somerville (4), was used for both straw and fibre samples. The straw samples (totally extracted) were given three chlorinations of 15, 10, and 5 minutes, while the fibre samples (solvent extracted) were completely delignified with two chlorinations of 10 and 5 minutes respectively.

(iv) *Uronic Acids.*

For this determination Campbell's apparatus and Campbell's modifications (5) of the method of Dickson, Otterson, and Link (6) were employed.

3. Results of Analyses.

TABLE 1.—STRAW ANALYSES.

Showing the results calculated back as percentages of the oven-dry original unretted straw.

	(1) Unretted original straw.	(2) Bacterially retted straw.	(3) Acid treated straw (N/50 HCl).	(4) Chemically retted straw. N/50 HCl followed by N/50 NaOH + 0·125 per cent. oleic acid.)	(5) Chemically retted straw. (N/50 HCl followed by N/50 NaOH + 0·21 per cent. oleic acid.	(6) Chemically retted straw. (N/50 HCl followed by N/50 NaOH. *No oleic acid.*)	(7) Chemically retted straw. (N/50 HCl followed by N/30 Na_2CO_3 + 0·21 per cent. oleic acid.)	(8) Chemically retted straw. (N/50 HCl followed by N/30 Na_2CO_3. *No oleic acid.*)
Ether soluble	1·5	1·4	1·2	2·1	2·2	0·7	1·8	0·5
Results calculated to oil-free (ether-soluble free) weights:—								
Benzene-alcohol soluble	2·7	0·1	0·8	0·1	0·1	0·1	0·1	0·0
Alcohol soluble	1·1	0·4	0·7	0·3	0·2	0·4	0·3	0·7
Soluble in hot water	7·5	1·9	3·3	2·1	1·4	1·9	1·6	2·0
Soluble in cold 5·0 per cent. NaOH	16·2	15·9	16·8	15·5	15·2	15·1	12·9	11·7
Soluble in hot 0·05 per cent. HCl	4·2	2·5	1·9	1·8	2·0	1·8	1·7	2·0
Soluble in cold 5·0 per cent. NH_4OH	1·7	0·6	0·7	0·8	0·8	0·3	0·3	0·5
Total extractable material	29·6	20·9	22·7	20·2	19·4	19·1	16·5	16·2
Cellulose (Cross and Bevan) on extracted sample	49·2	46·7	49·3	47·5	47·6	47·5	49·0	49·1
Total xylan (after solvent extraction)	16·3	14·5	15·5	14·1	14·3	14·0	13·2	13·3
Xylan in totally extracted sample	4·8	4·3	5·0	4·5	4·6	4·6	4·5	4·7
Xylan not in cellulose (after extraction)	0·9	0·8	1·1	0·9	0·9	1·1	0·7	0·8
Xylan in cellulose calculated as percentage of original material	3·9	3·5	3·9	3·6	3·7	3·5	3·8	3·9
Lignin in solvent extracted material	18·9	18·3	18·0	17·9	18·3	17·4	17·3	17·2
Lignin in totally extracted material	15·5	14·7	..	..	..	..	..	..
Uronic acids	8·2	4·7	6·8	4·7	4·0	5·0	3·8	3·7
Ash of original sample	1·2	0·3	0·4	0·9	0·7	0·9	1·2	1·4
Loss due to retting	..	15·4	8·9	15·4	15·9	15·0	17·1	16·8

Table 2.—Straw Analyses.

Showing the losses of the constituents of flax straw during the retting treatments.

These figures are taken from Table 1, where the results are expressed as percentages of the oven-dry, oil-free weights.

	(2) Bacterially retted straw.	(3) Acid treated straw. (N/50 HCl.)	(4) Chemically retted straw. (N/50 HCl followed by N/50 NaOH + 0·125 per cent. oleic acid.)	(5) Chemically retted straw. (N/50 HCl followed by N/50 NaOH + 0·21 per cent. oleic acid.)	(6) Chemically retted straw. (N/50 HCl followed by N/50 NaOH. *No oleic acid.*)	(7) Chemically retted straw. (N/50 HCl followed by N/30 Na_2CO_3 + 0·21 per cent. oleic acid.)	(8) Chemically retted straw. (N/50 HCl followed by N/30 Na_2CO_3. *No oleic acid.*)
Benzene-alcohol solubles ..	− 2·6	− 1·9	− 2·6	− 2·6	− 2·6	− 2·6	− 2·7
Alcohol solubles	− 0·7	− 0·4	− 0·8	− 0·9	− 0·7	− 0·8	− 0·4
Soluble in hot water	− 5·6	− 4·2	− 5·4	− 6·1	− 5·6	− 5·9	− 5·5
Soluble in cold 5·0 per cent. NaOH	− 0·3	+ 0·6	− 0·7	− 1·0	− 1·1	− 3·3	− 4·5
Soluble in hot 0·05 per cent. HCl	− 1·7	− 2·3	− 2·4	− 2·2	− 2·4	− 2·5	− 2·2
Soluble in cold 5·0 per cent. NH_4OH	− 1·1	− 1·0	− 0·9	− 0·9	− 1·4	− 1·4	− 1·2
Total extractable material ..	−12·0	− 9·2	−12·8	−13·7	−13·8	−16·5	−16·6
Cellulose (Cross and Bevan) on extracted sample	− 2·5	+ 0·1	− 1·7	− 1·6	− 1·7	− 0·2	− 0·1
Total xylan (after solvent extraction)	− 1·8	− 0·8	− 2·2	− 2·0	− 2·3	− 3·1	− 3·0
Xylan in totally extracted sample	− 0·5	+ 0·2	− 0·3	− 0·2	+ 0·3	− 0·3	− 0·1
Xylan not in cellulose (after extraction)	− 0·1	+ 0·2	− 0·0	− 0·0	+ 0·3	− 0·2	− 0·1
Xylan in cellulose calculated as percentage of original material	− 0·4	− 0·0	− 0·3	− 0·2	− 0·0	− 0·1	− 0·0
Lignin in solvent extracted material	− 0·6	− 0·9	− 1·0	− 0·6	− 1·5	− 1·6	− 1·7
Uronic acids	− 3·5	− 1·4	− 3·5	− 4·2	− 3·2	− 4·4	− 4·5
Ash of original sample	− 0·9	− 0·8	− 0·3	− 0·5	− 0·3	− 0·0	+ 0·2
Total retting loss	15·4	8·9	15·4	15·9	15·0	17·1	16·8

Table 3.—Fibre Analyses.

Showing the results calculated as percentages of the oven-dry, oil-free (ether-soluble free) weights.

	(2) Bacterially retted fibre.	(4) Chemically retted fibre. (N/50 HCl followed by N/50 NaOH + 0·125 per cent. oleic acid.)	(5) Chemically retted fibre. (N/50 HCl followed by N/50 NaOH + 0·21 per cent. oleic acid.)	(6) Chemically retted fibre. (N/50 HCl followed by N/50 NaOH. *No oleic acid.*)	(7) Chemically retted fibre. (N/50 HCl followed by N/30 Na_2CO_3 + 0·21 per cent. oleic acid.)	(8) Chemically retted fibre. (N/50 HCl followed by N/30 Na_2CO_3. *No oleic acid.*)
Ether solubles	2·7	4·6	3·2	1·7	2·5	1·5
Results calculated to oil-free (ether-soluble free) weights :—						
Soluble in hot water	2·9	2·5	..	..	..	..
Soluble in cold 5·0 per cent. NaOH ..	6·6	8·6	..	..	..	..
Soluble in hot 0·05 per cent. HCl ..	2·9	2·3	..	..	..	..
Soluble in cold 5·0 per cent. NH_4OH ..	0·2	0·2	..	..	..	..
Total extractable material	12·6	13·6	..	..	..	..
Cellulose (Cross and Bevan) on totally extracted material (*a*)..	86·1	84·9	..	..	..	..
Cellulose (Cross and Bevan) on solvent extracted material (*b*)	92·6	90·5	94·1	92·3	93·4	92·4
Total xylan (after solvent extraction) ..	2·7	3·6	2·4	3·3	2·7	3·4
Xylan in totally extracted material ..	0·2	0·3	..	..	..	..
Xylan not in cellulose (*a*)	0·0	0·0	..	..	..	..
Xylan not in cellulose (*b*)	1·3	1·8	1·1	1·8	1·0	1·6
Xylan in cellulose (*a*) calculated as percentage of original material	0·3	0·4	..	..	..	..
Xylan in cellulose (*b*) calculated as percentage of original material	1·4	1·8	1·3	1·5	1·7	1·8
Lignin in solvent-extracted material ..	3·5	4·3	4·2	4·4	4·1	4·7
Lignin in totally extracted material ..	2·1	2·1	..	..	..	..
Uronic acids	2·9	4·6	..	..	..	..
Ash in original material	0·4	1·3	0·5	0·9	0·5	1·1

TABLE 4.—FIBRE ANALYSES.

Showing the constituents of the fibre from the bacterial ret (2) and chemical ret (4) calculated as percentages of the original unretted straw and their respective retted straws (oven-dry).

	Bacterially Retted Fibre (2).		Chemically Retted Fibre (4).	
	Calculated as Percentage of Original Straw.	Calculated as Percentage of Retted Straw.	Calculated as Percentage of Original Straw.	Calculated as Percentage of Retted Straw.
Ether solubles	0·6	0·7	1·1	1·3
Soluble in hot water	0·6	0·8	0·6	0·7
Soluble in cold 5·0 per cent. NaOH	1·5	1·7	2·0	2·3
Soluble in hot 0·05 per cent. HCl	0·6	0·8	0·5	0·6
Soluble in cold 5·0 per cent. NH_4OH	0·1	0·1	0·1	0·1
Total extractable material	2·8	3·3	3·1	3·7
Cellulose (Cross and Bevan) on extracted sample	18·9	22·4	19·5	22·8
Total xylan (after solvent extraction)	0·6	0·7	0·8	1·0
Xylan in totally extracted sample	0·1	0·1	0·1	0·1
Xylan not in cellulose (after extraction)	0·0	0·0	0·0	0·0
Xylan in cellulose as percentage of original material	0·1	0·1	0·1	0·1
Lignin in solvent-extracted sample	0·8	0·9	1·0	1·2
Lignin in totally extracted sample	0·5	0·5	0·5	0·6
Uronic acids	0·6	0·8	1·1	1·2
Ash of original sample	0·1	0·1	0·3	0·3
Yield of fibre	22·6	26·7	24·1	28·2

4. Discussion of Results.

(i) *The determination of any essential chemical differences which exist between chemically and bacterially retted flax straw and fibre.*

(*a*) *Straw.*—With the exception of the ether-soluble fractions, the value of which depended on whether oleic acid had been added to the second boiling treatment, the analyses of the chemically and bacterially retted straw samples were very similar.

Where sodium carbonate had been used in the second boil, the fraction soluble in cold 5.0 per cent. sodium hydroxide was reduced, thus giving a lower value for the total extractable material and a correspondingly higher figure for the cellulose. This reduction in totally extractable material was also responsible for the presence of less total xylan, lignin, and uronic acids.

In all the chemically retted samples the cellulose content appeared to be higher than in the bacterially retted straw, but this could be accounted for by the differences in the total extractable material.

As the ash contents of all the chemically retted samples were higher than that obtained for the bacterially retted straw, there was evidently some deposition of neutral salts during the chemical treatment.

(*b*) *Fibre.*—All the chemically retted fibre samples showed that the values obtained for the ether-soluble fractions again depended on whether oleic acid had been used in the second boiling treatment.

The total lignin content of the chemically retted samples was higher in every case than that determined in the bacterially retted fibre, while the lignin values on the two totally extracted samples 2 and 4 were identical, showing that the discrepancies in the lignin figures were closely related to the differences in the extractable material.

Except in the case of sample 4, the cellulose contents of all the samples were practically identical with, or slightly higher than, the amount contained in the bacterially retted fibre. The presence of 1 per cent. more total extractable material in sample 4 could account for almost all the difference in the two cellulose figures obtained for samples 2 and 4. Fibre sample 4 appeared to be the least satisfactory of the three samples which had been treated with oleic acid in the second boil. Nevertheless the discrepancies of this sample from the bacterially retted fibre were very small.

When the figures for the fibre samples 2 and 4 were calculated as percentages of the original unretted and respective retted straws (Table 4), the two samples were seen to be remarkably similar. The 1.5 per cent. greater fibre yield obtained in the case of sample 4 could be accounted for by small differences in the ether solubles, total extractable material, and cellulose.

The ash contents of all the chemically retted samples were higher by variable amounts (probably depending on the efficiency of the washing treatment after the second boil) than that obtained for the bacterially retted fibre.

(ii) *A comparison of the retting losses incurred by the bacterially and chemically retted straws.*

There was no doubt that the retting losses incurred by the chemically retted straw samples were in all cases of the same order as the losses recorded during the bacterial ret (Table 2). Where N/30 sodium carbonate was used instead of N/50 sodium hydroxide in the second boil (samples 7 and 8), the loss of total extractable material was greater than for the other samples. This was due to the higher alkalinity of the N/30 sodium carbonate, which caused a greater loss in the fraction soluble in 5.0 per cent. cold sodium hydroxide. These higher retting losses did not appear to have any effect on the resultant fibre from these samples.

(iii) *The part played by the first treatment (viz., boiling with N/50 hydrochloric acid) in the retting.*

During the first boiling treatment more than half the total retting loss was accounted for. Three of the fractions, viz., the ether solubles, sodium hydroxide solubles, and cellulose, remained unchanged, while more than half the total loss in the values of the remaining fractions was effected.

These results indicated that a very considerable degree of the total hydrolysis was due to the boiling with weak acid, and it was therefore concluded that this treatment was essential for the production of a chemically retted fibre.

(iv) *The effect on the retting of the use of oleic acid in the second treatment.*

An examination of all the results showed that the presence of oleic acid in the second treatment was necessary either to prevent the diminution of the natural oil in the fibre or to replace that which was saponified during the treatment by the deposition of sodium oleate. There was no definite evidence that the actual retting was facilitated by the addition of oleic acid, nevertheless it was possible that it might be of assistance in keeping down the lignin content of the fibre.

Although the values of the ether-soluble fractions of the chemically retted straw and fibre samples were higher than that of the bacterially retted sample when oleic acid had been added to the second boil, and lower when no oleic acid was present, there appeared to be no relation between the amount of oleic acid used in the treatment and the quantity found in either the straws or fibres. Straw samples 5 and 7, which were boiled in a solution containing a greater percentage of oleic acid than sample 4, produced a less oily fibre. Cupples (7) found that the wetting and spreading properties of oleic acid used in conjunction with sodium hydroxide or sodium carbonate were very sensitive to concentration changes. These discrepancies were therefore probably due to either better penetration of the straw giving a more even distribution of the sodium oleate, or less deposition on the surface of the straw in treatments 5 and 7 than treatment 4. The use of the sodium carbonate in place of sodium hydroxide in conjunction with oleic acid caused a decrease in the oil content of the fibre, bringing it almost to the same value as that obtained for the bacterially retted sample.

(v) *A comparison of the relative merits of sodium hydroxide and sodium carbonate as retting agents in the second treatment.*

Where sodium carbonate was used in conjunction with oleic acid in the second treatment (viz., 7) analysis of the resultant fibre compared very favorably with the figures for the bacterially retted sample. The oil content was almost identical and the lignin figure was the lowest of all the chemically retted samples, but not quite as low as that obtained on the fibre from the bacterial ret. For these reasons there appeared to be every justification for recommending the use of sodium carbonate as a retting agent.

5. Conclusion.

Although successful chemical retting of flax straw appears to be a foregone conclusion, a great deal more systematic work is required, particularly with regard to the quantities of oleic acid necessary, before it can be recommended as a routine procedure.

6. Acknowledgment.

The author wishes to record her appreciation of the assistance and advice which was given by Dr. W. E. Cohen, especially as regards the methods of analysis which were employed.

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The Soil Clay Mineralogy of Some Australian Soils Developed on Granitic and Basaltic Parent Material.*

By J. S. Hosking, M.Sc.†

Summary.

The colloidal fractions separated from the subsoils of a number of Australian soils have been examined by means of X-ray diffraction technique and their soil clay minerals identified.

Kaolinitic clay types are shown to characterize each one of a series of granitic soils examined, irrespective of the conditions under which they were formed. In the case of basaltic soils, however, the type of clay mineral present is a reflection of the soil moisture conditions under which they have developed; kaolinitic types alone characterize the red loams, montmorillonitic types together with a little kaolinite prevail in the red brown earths, while montmorillonite alone is typical in the black earths. Where climatic conditions would appear to lead normally to the development of the kaolinitic type, restrictions in free drainage are shown to produce a montmorillonitic clay on soils formed over certain basic rocks.

Accessory quartz, hydrargillite (Gibbsite) and goethite and/or haematite are also present in certain soils.

1. Introduction.

The important part played by the clay or colloid fraction in determining the properties of the soil has long been recognized, but since the small particle size of this material did not permit the application of current methods of mineralogical technique, early attempts to determine its constitution were confined almost entirely to chemical analyses. With the application of X-ray diffraction methods in the examination of soil colloids (Hendricks and Fry, 1930; Kelley, Dore, and Brown, 1931), however, the essentially crystalline nature of the fraction was definitely established, and with further advances made since that time in the precision of the methods, it is now possible to identify the mineral species present. It is still necessary, nevertheless, to supplement X-ray technique by chemical analyses, thermal methods, and optical data in order to determine quantitatively the relative amounts of the minerals.

The purpose of the present investigation has been to identify by means of X-ray diffraction technique the clay minerals present in a number of Australian soils formed *in situ* over certain igneous rocks, and to find out whether there was any relationship between the type of clay mineral and the parent material of the soils.

2. Soil Clay Minerals.

The clay minerals, in common with the micas, chlorites, vermiculites, &c., have been shown by Pauling (1930) to have closely similar structures, in that they all contain alumino-silicate layers, within which there is frequent isomorphous replacement of one ion for another, and

* The X-ray examination of the clays was carried out at the University of California in California, U.S.A., during the author's visit there in 1939.

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between which there is perfect cleavage. Individual crystals contain many superimposed layers. Gruner (1934) and Hendricks and Jefferson (1938) have shown that, in addition, minerals can be formed by the interstratification of different kinds of layers, and thus it is possible for minerals to be made up of mixed layers of montmorillonite, pyrophyllite, micas, vermiculites, &c.

Although there are, necessarily, still certain doubts in regard to crystal structures and some confusion in nomenclature, a satisfactory grouping of the clay minerals, from the pedological point of view, has been made into (*a*) kaolin minerals,* (*b*) montmorillonitic minerals,* (*c*) hydrous micas, (*d*) accessory oxides and hydrous oxides. The groups will only be briefly described here, but for a comprehensive survey of the field and for excellent references to the literature of soil clay mineralogy, Kerr (1938), Hendricks and Alexander (1939), Nagelschmidt (1939), and Hosking (1940) should be consulted.

(*a*) The kaolin minerals include kaolinite, halloysite, and hydrated halloysite, nacrite, and dickite, of which only the first two have so far been reported as occurring in soils. The members of the group have the idealistic formula $[Al_2]\,[Si_2]\,O_5(OH)_4$ or $Al_2O_3.2SiO_2.2H_2O$ (hydrated halloysite, $4H_2O$) and an ideal $SiO_2:Al_2O_3$ ratio of 2:1. Isomorphous replacement in these minerals is restricted to that of Al for Si or Si for Al (with a consequent variation in the $SiO_2:Al_2O_3$ ratio), since it is impossible from structural considerations (Pauling, 1930) for either Fe or Mg to replace Al in this mineral type. Hendricks (1939) has recently examined the mineral cronstedite, formed of kaolinite-like layers superimposed with a random mixing of three possible structures, containing ferric ions, and it is probable that a mineral of this type may be present in clays of the kaolinite type, in which iron occurs in combination with silica.

(*b*) Clay minerals of the montmorillonitic type may be related to the ideal formula $[Al_2]\,[Si_4]\,O_{10}(OH)_2 + xH_2O$ or $Al_2O_3.4SiO_2.H_2O + xH_2O$ with a $SiO_2:Al_2O_3$ ratio of 4:1. Extensive replacements within the lattice occur. Substitution of Mg for Al gives rise to the so-called magnesium "bentonites," whereas similar substitution by Fe, principally as the ferric ion, leads eventually to the mineral nontronite. Where in addition to these replacements Al may be substituted for Si, minerals similar to beidellite are formed, with a $SiO_2:R_2O_3$ ratio approximating to 3:1 in many instances. Minerals of this type are characterized by their ability to take up water reversibly between the lattice layers, resulting in definite swelling properties of the minerals. Hendricks and Alexander (1939) rather question the common occurrence of individual montmorillonite crystals in soil clays; mixed layer minerals in their opinion are much more frequent.

(*c*) The third group includes those clay minerals related to the micas which, owing to their higher moisture content, have been referred to by Hendricks and Alexander (1939) as hydrous micas. Grim, Bray, and Bradley (1937) proposed the name illite for their type sample, isolated from a series of argillaceous sediments in Illinois. They related the formula to that of the ideal mica, $K[Al_2]\,[AlSi_3]O_{10}(OH)_2$, in

* The terms kaolinite and montmorillonite, used without qualification in this paper, refer to a mineral of the group and not necessarily to the specific mineral named.

which there was a replacement of K by H_2O accompanied by substitution of Si for Al in tetrahedral co-ordination or of (OH) for O. The minerals like the micas themselves contain appreciable replacement of Al (in octahedral co-ordination) by Mg and Fe.

(*d*) Free and hydrous oxides of silicon, iron, or aluminium are present in most soils. Free silica is fairly uniformly distributed in soils, either in the amorphous state, or as crystalline quartz (SiO_2) or crystobalite (SiO_2). Of the iron minerals goethite (FeO(OH)), haematite (Fe_2O_3), and amorphous limonite (FeO(OH) to $Fe(OH)_3$) are common, and magnetite ($FeO.Fe_2O_3$) is also found. Hydrous oxides of aluminium in the form of Gibbsite or hydrargillite (bauxite) ($Al(OH)_3$) and diaspore or boehmite (AlO(OH)) have also been reported.

Such resistant minerals as rutile (TiO_2), ilmenite ($FeTiO_3$), leucoxene (alteration product of ilmenite, $CaTiSiO_5$), and zircon ($ZrSiO_4$) have also been identified in soil clays.

3. Colloids Examined.

Nineteen Australian colloid or clay samples have been examined. These represent eight soils formed on granitic parent material, seven soils on basaltic material, two on dioritic or basic rock, and finally two samples, one an immature soil on recent pumiceous volcanic ash and the other a fresh volcanic deposit, representing the original parent material of the former. Climatic and other data relating to the soils are given in Table 1, the last column of which gives references to the literature in which detailed descriptions of the soils may be found.

As will be seen from the table, there is a variation in annual rainfall of from 48 inches to about 7 inches for the granitic soils and from 66 inches to 15 inches for the soils formed over basalts, and corresponding ranges in annual temperature from 74°F. to 56°F. for the former and from 74°F. to 52°F. for the latter. In order to present more clearly the effectiveness of the rainfall, as it may be related to the moisture conditions within the soil and consequently to soil developmental trends, the ratio of precipitation to saturation deficiency of the atmosphere for every month of the year has been calculated. Two critical values for this ratio have been determined (Prescott, 1936, 1938), the first a monthly ratio of 5, and the second a somewhat indefinite one at present, but somewhat less than 35. Where the former value is not reached in any month drought conditions prevail; furthermore, when for no month of the year is the value exceeded, desert conditions are apparent. On the other hand, the second ratio indicates conditions of real wetness in the soil, with resultant active leaching taking place.

The granitic soils are thus represented by a series, varying from true podsols, in which leaching processes are active for certain months of the year and at no time is there a real moisture deficiency, to a desert type in which drought conditions prevail for eleven months of the year. Also included is a soil from tropical Australia of granitic origin, developed under high summer rainfall and winter drought. While the soils on basaltic parent material do not represent such extremes of developmental processes, they cover a range of soil types including red loams, a red-brown earth, a chestnut earth, and black

TABLE 1.—CLIMATIC AND OTHER DATA REGARDING THE SOILS FROM WHICH THE COLLOIDS WERE SEPARATED.

Parent Material.	Zonal Soil Type.	Locality.	Mean Annual Rainfall (inches).	Mean Annual Temperature °F.	Months of year soil subject to drought.	Sample Number.	Depth of Sample (inches).	Clay <2μ. %	Ratio* of $\frac{\text{Clay in B}}{\text{Clay in A}}$	Reference.
Granitic	Podsol ..	King Island, Tasmania	33·9	56	0	2187	33–42	34	8·7	Stephens and Hosking, 1932
	Yellow podsolized	Denmark, Western Australia	48·2	60	0	3998	23–36	39	3·2	Hosking and Burvill 1938
	Yellow podsolized	Mundaring Weir, Western Australia	42·8	63	5	3401	30–50	41	2·6	†
	Yellow podsolized	Near Katherine, Northern Australia	37·7	81	7	5262	20–32	14	3·7	†
	Grey podsolized	Uralla, New South Wales	31·2	56	0	1200	18–27	44	4·6	†
	Red brown podsolized	Wambanumba, New South Wales	24·9	59	0	1375	18–27	61	4·2	†
	Red brown earth	Charters Towers, Queensland	25·3	74	6	3441	15–24	26	2·3	†
	Semi-desert ..	Glenorchy, South Australia	7·3	66	11	4605	14–26	24	3·4	Prescott and Skewes, 1938
Dioritic or basic rock	Red brown podsolized	Denmark, Western Australia	48·2	60	0	3948	24–36	35	2·2	Hosking and Burvill, 1938
	Red brown podsolized	Denmark, Western Australia	48·2	60	0	4373	27–42	38	3·1	Hosking and Burvill, 1938
Basaltic	Red loam ..	Coolangatta, Queensland	69·0	66	0	902	18–27	64	1·2	Prescott and Hosking, 1936
	Red loam ..	Scottsdale, Tasmania ..	43·0	52	0	3887	21–50	66	1·4	Stephens, 1937
	Red earth ..	Myola, Queensland ..	25·3	74	6	3449	32–42	58	1·5	†
	Red brown earth	Gunnedah, New South Wales	23·4	65	1	1007	18–27	55	1·3	Prescott and Hosking, 1936
	Chestnut earth ..	Mirrool, New South Wales	15·8	63	6	1845	19–27	50	1·0	†
	Black earth ..	Ilparran, New South Wales	31·3	56	0	1216	6–20	51	1·1	Hosking, 1935
	Black earth ..	Orion Downs, Queensland	26·3	71	5	1048	9–18	62	1·0	Hosking, 1935
Pumiceous volcanic ash	Immature ..	Rabaul, New Guinea ..	88·4	82	..	5386	9–14	11	0·5	Hosking, 1938
	Fresh deposit ..	Rabaul, New Guinea ..	88·4	82	..	5206	4	21	..	Hosking, 1938

* B = Subsoil or B horizon. A = Surface or A horizon. † Waite Institute Records.

soils. In the case of the first-named type, the climate allows of leaching operations for a period of several months of the year and the complete absence of drought; for the remaining types leaching is restricted to absent, and drought conditions may persist for as long as six months. In the area from which the volcanic pumiceous soil of New Guinea was taken, an extremely high rainfall is modified by high evaporation control; while drought conditions are never approached, water movement down through the profile is restricted to about five months of the year.

4. Separation of the Clays.

The clay fraction was separated from subsoil or B horizon samples of each profile, by preliminary dispersion of the soil with sodium carbonate and repeated decantations, on the basis of sedimentation through 8.6 cm. in 24 hours. The maximum diameter of the particles thus obtained would be slightly greater than 1μ. The separated clays were flocculated with calcium chloride, filtered, and washed with alcohol. Following treatment with dilute acid to remove contaminating calcium carbonate, the clays were further treated with hydrogen peroxide to destroy organic matter. After this oxidation the samples were leached with neutral calcium chloride to ensure calcium saturation, then with alcohol to remove excess salt, dried and crushed to pass 1-mm. sieve, and stored. Samples for X-ray examination were further crushed to pass 100-mesh sieves.

5. X-ray Examination.

X-ray diffraction patterns from each of the colloids and certain mineral samples were obtained by the use of molybdenum radiations rendered virtually monochromatic by filtration through zirconia screens. The prepared colloids, packed in thin-walled soft glass tubes, with an internal diameter of about 0.6 mm., were exposed in cylindrical casettes having a radius of 20.32 cm., so designed that spacings up to about 40Å would register.

Interplanar spacings corresponding to all the recognizable lines recorded on the diffraction patterns were calculated. By comparison with suitable reference data, and with patterns of authentic mineral samples, it has been possible to determine the class of clay mineral present, and in addition to draw further conclusions with regard to the minor constituent accessory minerals. Kelley and his co-workers (1939), accepting only spacings relating to definite unit cells for which definite Miller indexes could be assigned, have on the basis of the spacings given by Gruner (1932) for kaolinite, by Maegdefrau and Hofmann (1937) for montmorillonite, and by Grim, Bray, and Bradley (1937) for the hydrous mica illite, selected and tabulated the spacings of value in interpreting soil data; these data, together with their recorded spacings for certain accessory minerals, have been utilized in the present work.

X-ray diagrams, of four typical clays only, are plotted in Fig. 1, with lattice spacings as abscissae on a logarithmic scale, and with intensity in seven equal steps as the ordinate (Nagelschmidt, 1939). The individual letters above a particular line indicate merely those

minerals which might be responsible for the particular line or spacing indicated, and not that the mineral is necessarily present. The minerals identified from the patterns for each of the 19 clays are listed in Table 2.

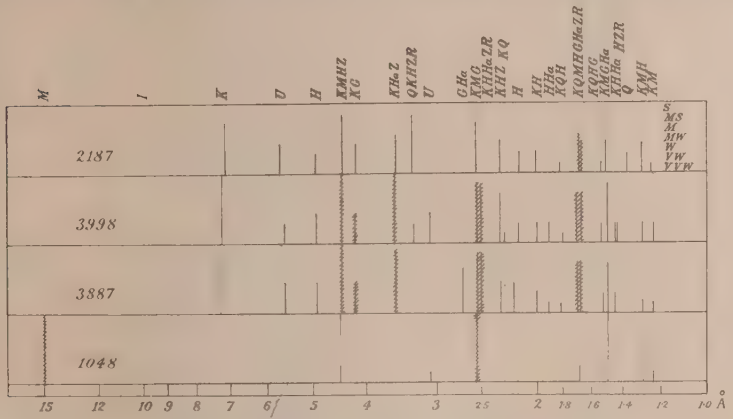

FIG. 1.—X-ray diffraction data for 4 typical clay samples. Data plotted with lattice spacings as abscissae on a logarithmic scale and intensity as the ordinate (symbols for intensity S = strong, M = medium, W = weak, V = very). Letters above the various lines indicate that the spacing might be due to the presence of the mineral indicated, not that the presence of the mineral is necessarily established by the line (G = goethite, H = hydrargillite, Ha = haematite, I = Hydrous mica, K = kaolinite, M = montmorillonite, Q = quartz, R = rutile, Z = zircon, U = unidentified mineral). Hatching indicates a broadening of the lines so marked.

(a) Granitic Soils.

A spacing of about 7Å, characteristic of the mineral kaolinite, is present on the X-ray films for all the colloids separated from the soils formed over granitic parent material, whereas the wide spacings for both montmorillonite and the hydrous micas are entirely absent. In addition the entire reference pattern of kaolinite is present, thus indicating clearly the kaolinite nature of these colloids. The presence of lines which cannot be related to the former mineral, and the stronger intensities of certain lines associated with kaolinite, indicate the presence of subsidiary minerals; quartz is present in sample 2187 and probably in samples 4605 and 5262. From a consideration of the hydrargillite (Gibbsite) pattern, sample number 3998 undoubtedly contains this mineral, and it is possibly also present in samples 2187, 3401, 1200, 4605, and 5262. Goethite and/or haematite may be considered present in sample 1375 and probably in one or two of the others.

(b) Basaltic Soils.

The basaltic soils, unlike the granitic soils, do not show a single characteristic clay mineral throughout the range of samples examined. The red loams like the granitic soils show the characteristic 7Å spacing and subsidiary pattern of kaolinite, with certain lines also indicative of the presence of hydragillite, goethite, and haematite. A strong 15Å spacing for the red-brown earth and chestnut earth samples indicates

TABLE 2.—CLAY MINERALS IDENTIFIED IN SOIL COLLOIDS UNDER EXAMINATION.

Parent Material.	Zonal Type.	Locality.	Sample Number.	Colour of Colloid.	Clay Minerals Identified.		$\frac{SiO_2}{Al_2O_3}$.	$\frac{SiO_2}{R_2O_3}$.
					Characteristic.	Also present.		
Granitic ..	Podsol ..	King Island ..	2187	Light grey to white	Kaolinite * ..	Quartz, *hydrargillite*† ..	..	..
	Yellow podsolized	Denmark ..	3998	Creamy yellow ..	Kaolinite ..	Hydrargillite	1·33	1·18
	Yellow podsolized	Mundaring Weir	3401	Creamy pink ..	Kaolinite ..	*Hydrargillite*	..	..
	Yellow podsolized	Near Katherine	5262	Light brown ..	Kaolinite ..	Quartz	..	..
	Grey podsolized	Uralla ..	1200	Brownish yellow	Kaolinite ..	*Hydrargillite*	..	..
	Red brown podsolized	Wambanumba	1375	Red	Kaolinite ..	Goethite and/or haematite	..	..
	Red brown earth	Charters Towers	3441	Pinkish brown ..	Kaolinite ..	‡	..	..
	Semi-desert ..	Glenorchy ..	4605	Light brown ..	Kaolinite ..	Quartz, *hydrargillite* ..	..	..
Dioritic or basic rock	Red brown podsolized	Denmark ..	3948	Light red brown	Kaolinite ..	Hydrargillite, goethite, and haematite	1·46	1·08
	Red brown podsolized	Denmark ..	4373	Light greenish grey yellow	Montmorillonite	Kaolinite, quartz ..	3·23	2·14
Basaltic ..	Red loam ..	Coolangatta ..	902	Reddish brown ..	Kaolinite ..	Hydrargillite, goethite, and/or haematite	1·79	1·44
	Red loam ..	Scottsdale ..	3887	Dark red ..	Kaolinite ..	Hydrargillite, goethite, and/or haematite	..	..
	Red earth ..	Myola ..	3449	Reddish brown ..	Kaolinite ..	‡	..	..
	Red brown earth	Gunnedah ..	1007	Dark brown to chocolate	Montmorillonite§	Kaolinite, quartz ..	3·67	2·85
	Chestnut earth ..	Mirrool ..	1845	Dark red brown	Montmorillonite	Kaolinite, quartz ..	..	..
	Black earth ..	Ilparran ..	1216	Chocolate brown	Montmorillonite	.. .. ..	..	..
	Black earth ..	Orion Downs ..	1048	Very dark brownish black	Montmorillonite	.. .. ..	..	..
Pumiceous volcanic deposits	Immature ..	Rabaul ..	5386	Light brownish grey	Kaolinite ..	.. .. ..	..	..
	Fresh deposits ..	Rabaul ..	5206	Grey	Montmorillonite	Kaolinite	..	..

* Kaolinite or related mineral. † Minerals in italics only probable. ‡ Faint Patterns. § Montmorillonite or related minerals.

their typical montmorillonitic nature, while a weak 7Å spacing shows that kaolinite is not completely absent. The relative intensity of the 3.3Å spacing shows the presence of quartz. In the case of the black earths a strong 14Å spacing with a diffraction pattern, which may be compared in its entirety to that of montmorillonite, shows that probably this mineral alone (apart from amorphous material) is present in these colloids.

(*c*) *Soils formed on basic (dioritic) rock.*

Of the two soils developed on basic rock from the Denmark area, the one 3948 shows the 7Å spacing and subsidiary pattern of kaolinite well developed. In addition to the kaolinite which characterizes the sample, hydrargillite, goethite, and/or haematite may be considered to be present. Sample 4373, while showing a very weak spacing at 7Å and hence the presence of a small proportion of kaolinite, has a marked montmorillonitic pattern developed in its entirety. The probable reason for the differential development of the two mineral species will be discussed in the next section.

(*d*) *Volcanic pumiceous deposit and soil from New Guinea.*

The patterns obtained from the colloids separated from the volcanic ash and from the soil formed over similar parent material showed a general darkening of the background, and the diffraction lines were not in every instance easy to distinguish. These facts indicate rather less crystallinity than in most of the other samples examined. The soil colloid showed the characteristic 7Å spacing with the subsidiary spacings, all in agreement in intensity and position with those of kaolinite alone. In the ash sample both a 15Å and a 7Å line were present in about equal intensity. In addition to remaining lines which could be related to either the montmorillonite or kaolinite patterns, there were further lines which could neither be related to unidentified lines of soil patterns or to any other minerals so far examined. While the presence of both kaolinite and montmorillonite are indicated, it is quite understandable that mineral species are present, which are in no ways related to those present in soils.

6. Discussion.

Apart from some heterogeneity in regard to the presence of the accessory minerals, there is a certain uniformity of occurrence of the clay mineral types in the soils that have been examined.

It is apparent that granitic types of parent material will weather to kaolinite or halloysite under a very wide range of climatic conditions. Whereas the clay type may remain constant, the variation in mineralogical composition of the granite is reflected to a certain extent in the minor constituents of the clay. The granites from King Island, Denmark, and Mundaring Weir are, apart from biotite, fairly free from ferro-magnesian minerals, whereas the varieties from Charters Towers and Wambanumba are rich in augite or hornblende. While a little free iron, probably amorphous limonite, is present in the clay from the Denmark sample, where lateritic residues in the soil are a prominent feature, the accessory minerals are either quartz at King Island or hydrargillite at Denmark and Mundaring Weir. The higher iron content of the Wambanumba granite is reflected in the presence of crystalline goethite and/or haematite.

In the case of the basaltic soils, the internal moisture conditions and developmental trends appear to play an important part in determining the mineral clay type formed. Under excessive moisture and dominant leaching conditions, where free drainage is a feature and there is no approach to drought conditions for any period of the year, basaltic parent materials give rise to colloids of the kaolinitic type. Hydrargillite, goethite, and haematite are a further expression of high sesquioxide content and conditions allowing complete oxidation. With a lowering of the moisture status, the practical cessation of active leaching, and the occurrence of protracted drought periods, montmorillonitic types become the characteristic mineral type. Where free drainage still prevails kaolinite may still be found, but in its absence montmorillonite alone occurs.

The three soils from Denmark, full descriptions of which are to be found in a report by Hosking and Burvill (1938), form an interesting series. Whereas number 3998 is a clay from a soil developed on granitic gneiss, numbers 3948 and 4373 are from soils developed upon diorites or basic rocks; the three soils are all influenced by the presence of lateritic or ferruginous gravels throughout their profiles. The first two profiles are characterized by good drainage conditions, allowing of complete oxidation, whereas the third (represented by sample 4373) is subject to a certain degree of waterlogging. The soils with good internal drainage, whether formed on granite or basic rock, are both characterized by a clay mineral of the kaolinitic type; the basic nature of the parent material of sample 3948 is, however, reflected in the presence of goethite and haematite which imparts a distinctly red-brown shade to the clay, as opposed to the creamy colour of the former. In the clay (4373) where waterlogging is apparent and free oxidation restricted, montmorillonite is formed to the almost complete exclusion of kaolinite. The absence of crystalline iron minerals, despite the high content of iron in the clay, is undoubtedly due to the restriction in oxidizing conditions, a fact reflected in the greenish colour of the clay. The types of clay mineral present are in accord with the molecular ratios shown in Table 2.

A comparison of the figures for free and total iron in the clays (Hosking and Burvill, 1938; Prescott and Hosking, 1936) indicates that a large percentage of the iron is definitely present in the clay complex. This fact has been strikingly brought out by the investigations of Beck (1939), who, from his examination of the colour of soils in relation to their free iron oxide content, showed that in many instances the yellow and brown colours were definitely intrinsic to the clays.

The clay minerals present in the samples from Coolangatta and Denmark contain some 6 per cent. or more of the iron in combination with silica. Since iron kaolinites cannot exist as such, it is suggested that an iron mineral similar to cronstedite may be present, in addition to kaolinite. Cronstedite (Hendricks, 1939) is characterized by a strong line at 7.1Å corresponding to the (003) spacing ($c_0 = 21.25$Å) which could not be distinguished from the (002) spacing of kaolinite. It is highly probable that a mineral of this type is present in many iron-rich kaolinitic clays.

A consideration of the chemical analyses and the X-ray diffraction pattern of sample 1007 suggests the presence of a montmorillonitic clay type with some [Fe] replacing [Al]. The presence of kaolinite in addition suggests a mixed mineral of a type similar to faratsihite (Hendricks, 1939).

From a knowledge of the mineral species identified from the X-ray diffraction patterns and the chemical analyses, the approximate percentage mineralogical composition of the clays from the four soils, numbers 3998, 3948, 902, and 1007 has been calculated as shown in Table 3.

Table 3.—Estimated Mineralogical Composition of Four Clay Samples.

Mineral.	3998.	3948.	902.	1007.
	%	%	%	%
Kaolinite	60	50	65	10
Iron silicate*	7	10	7	..
Hydrargillite	20	15	7	..
Goethite†	< 1	10	6	6
Montmorillonite	..	..	..	65‡
Quartz	..	..	..	6
Titanum minerals§	1	2	2	1

* Compare with cronstedite.
† Water of hydration in excess of all mineral calculations, therefore all free Fe_2O_3 calculated to goethite FeO(OH) and none to haematite.
‡ Contains some [Fe‴].
§ Titanium may be present as a constituent of other mineral types.
Balance in each case equals bases + adsorbed water.

In none of the soil samples examined was there any evidence of a mineral of the hydrous mica type. Kelley and his associates (1939) have shown the presence of a mineral of this type in the clays of the Hanford series, youthful soils formed upon recently transported material derived from a granitic source. It was expected that the soils from Denmark and Mundaring Weir, which contained large proportions of mica in the sand fractions, would contain micaceous clay minerals, but they were entirely absent. It is probable that under the type of weathering in the area, the mica of the finest fractions has been completely altered to kaolinite in these somewhat mature soils.

As far as the volcanic soil is concerned, the clay mineral present is definitely of the kaolinitic type. The presence of montmorillonite in the fresh volcanic ash deposit is more or less to be expected from its universal occurrence in volcanic bentonitic deposits. The presence of kaolinite is by no means so certain. Not only is the full kaolinitic pattern not apparent, but there are present in the X-ray diffraction pattern several lines which were not identifiable with any of those of the soil clay or accessory minerals considered. It is probable that in this case the spacing may be due to an unaltered silicate, as in the case of the Maxwell colloid (Kelley et al., 1939), where the 7Å spacing might be due to the mineral chrysotile (a member of the serpentine class) from which the Maxwell soil developed.

This work represents the commencement of a somewhat detailed study of the clay mineralogy of Australian soils, which is considered a necessary attribute to our understanding of certain problems associated with practical agriculture.

7. Acknowledgments.

The author wishes to express his appreciation to Professor Hoagland, Head of the Division of Plant Nutrition in the University of California, for allowing the use of the X-ray equipment, and to Mr. W. H. Dore, of the same Division, for his very helpful advice during the course of the X-ray work.

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(Boron Deficiency Symptoms on Pine Seedlings in Water Culture. See page 186.)

FIG. 1.—*Pinus radiata* grown for 4 months in humus and then for 3 months in nutrient solution—

(*a*) boron-deficient (left);

(*b*) plus boron, 0.5 p.p.m. (right).

Roots on a slightly larger scale than tops.

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PLATE 2

(Boron Deficiency Symptoms on Pine Seedlings in Water Culture. See page 186.)

FIG. 2.—*Pinus taeda* grown for 2 months in soil, 4 months in sand, and 4 months in nutrient solution—

(*a*) boron-deficient (above);

(*b*) plus boron, 0.5 p.p.m. (below).

(Boron Deficiency Symptoms on Pine Seedlings in Water Culture. See page 186.)

FIG. 3.—*Pinus laeta* grown for 14 months in the field and then for 4 months in nutrient solution:—
(*a*) boron-deficient (left).
(*b*) plus boron, 0·5 p.p.m. (right).

PLATE 4.

(Notes on the Control of Blackberry, Watsonia, Bracken, and Ragwort in Victoria. See page 178.)

FIG. 1.—Untreated area showing dense blackberry and Watsonia infestation at Dandenong, Vic.

FIG. 2.—An example of pasture of perennial rye, cocksfoot and white Dutch clover obtained on land similar to that shown in Fig. 1.

(Notes on the Control of Blackberry, Watsonia, Bracken, and Ragwort in Victoria. See page 178.)

FIG. 3.—A field at Toora showing dense bracken infestation. The ragwort is below the bracken fronds.

PLATE 6.

(Notes on the Control of Blackberry, Watsonia, Bracken, and Ragwort in Victoria. See page 178.)

FIG. 4. Pasture of perennial rye, cocksfoot and white Dutch clover on the experiment area.

NOTES.

Weevil Problem in Stored Wheat.

An investigation into methods of controlling weevils in wheat, and of protecting stored grain from weevil infestation, has been undertaken by the Council's Division of Economic Entomology at the request of the Australian Wheat Board. During the last war, when, as is the case to-day, a bumper crop combined with shipping difficulties resulted in the necessity of holding large quantities of wheat in store in Australia, various methods of treating infested grain were tried out. Ultimately, sterilization by heat and fumigation with carbon dioxide were successfully adopted on a large scale. No simple and effective method of protecting wheat from weevils was discovered, however, other than hygienic handling to reduce the risk of contamination, and the complete enclosure of stacks in an insect-proof covering.

In recent years a new method of controlling weevils in grain by means of chemically inert mineral dusts has been developed overseas, and has received a considerable amount of attention from scientists in various parts of the world. The dusts are mixed with the wheat in a concentration of 1 per cent. or 0.5 per cent. by weight. Provided the infestation has not proceeded too far (when the wheat will be moist, and will contain a large quantity of floury weevil frass), the dust will kill the adult weevils in the grain. Its efficacy is not transient, and thus it will protect the wheat from further infestation, and will kill those weevils which may subsequently emerge, and which, as eggs, larvae, or pupae confined within wheat grains, at first escaped the effects of the dust. In that it renders treated wheat safe from further infestation, dust treatment has an important advantage over fumigation and heat sterilization.

The use of inert dusts for weevil control must be regarded as still being in an experimental stage, although one such powder has been on the market for some years, and is understood to have been used for treating grain and cereal products exported from Europe to the East. The dust in question consists of finely-ground crystalline silica. As there are objections, from the health point of view, against the use of a dust of this nature, the Division of Economic Entomology has been carrying out experiments with the object of discovering an effective non-siliceous substitute, cheap and readily available in this country. The results obtained have been very encouraging.

Two species of weevil, *Calandra oryzae* (the rice weevil) and *C. granaria* (the granary weevil), damage grain in Australia, the former being by far the more serious pest. Luckily it is much more easy to control than is the latter species. Over half-a-dozen minerals, when ground to pass through a 200 mesh-to-the-inch sieve, have given effective control of the rice weevil in laboratory tests, which have been carried out under very severe conditions. Of these, two or three only appear to give complete control of the granary weevil, one of them being magnesite (magnesium carbonate). It may be mentioned that the dusts which have shown most promise in these preliminary experiments have given consistently better results than the proprietary siliceous dust mentioned above. They are now being subjected to more comprehensive and exhaustive tests.

Co-operation between the Council and the various State Entomologists has been established to cover the more general aspects of the wheat weevil investigation. Thus the Council for Scientific and Industrial Research and State officers are conducting observations and experiments with a view to filling in the gaps in the existing knowledge of the biology of the insects, and particularly to determine precisely the conditions which permit and inhibit weevil infestation and multiplication. It seems likely that the soundness of various decisions relating to practical policy that may have to be made will depend, very largely, on the accuracy of the information available on matters such as these.

Division of Industrial Chemistry—Appointments to Staff.

In a previous issue it was mentioned that the Government had made the sum of £50,000 available to the Council for the erection and equipment of a laboratory for the newly-formed Division of Industrial Chemistry, to be in charge of Dr. I. W. Wark.

Plans for the laboratory are almost complete, and it is expected that tenders for the actual constructional work will be invited late in August.

In the meantime, the authorities of various existing laboratories, e.g., those of the University of Melbourne and the Melbourne Technical College, have indicated their willingness to house such investigators as are appointed before the Division's own laboratories are available. Approval has accordingly been obtained for the initiation of work in certain fields, and for the immediate appointment of the necessary investigators. The lines of work which will be studied at once are as follows:—

(*a*) *Fellmongery.*—Nearly 70 per cent. of Australian exports of sheepskins have hitherto been exported to France, but since this trade will now cease, it will be necessary for Australian fellmongeries to be used to full capacity, and any method of increasing their annual output will be valuable. It is accordingly proposed to concentrate on this problem, and chiefly to study control of the atmosphere of the sweating chamber in order to get the skins into the correct condition for "pulling" at a specified time after hanging on the racks. At present, under winter conditions, about six days are required before pulling is possible, whereas in summer the bacteriological processes are advanced to the same extent in about two days. If satisfactory conditions could be devised for a two-day pulling period throughout the year, the capacity of the local plants would obviously be greatly increased. For this work it is proposed to appoint a biochemist, to be classified as a "Research Officer."

(*b*) *Dairy Research.*—In view of the possibility that the amount of shipping space available for the transport of foodstuffs to England may be curtailed in the future, it is evident that work on highly concentrated foodstuffs should be expedited. It is accordingly proposed

to make a commencement on the drying and concentrating of milk and milk by-products, and on processed cheese production. For these purposes a vacancy for a biochemist, to be classified as a "Research Officer," has been created.

(*c*) *Minerals Utilization.*—Nowadays, under wartime conditions, the Council is continually being asked for information concerning the possible utilization of different mineral deposits in Australia to make good shortages of imported raw materials or for use in the production of materials at present imported. In many cases the complete answer to these inquiries would involve research. It is proposed to appoint an inorganic chemist, to be classified as a "Research Officer," for work in this field.

(*d*) *Wool Investigations.*—The Council's work on wool shrinkage has already given an indication of the possibilities of research work in this field. Various textile interests in Australia have also given an indication that they would be willing to provide financial assistance for further work on textile research. There is a large field in the utilization of the many different constituents of wool wax; for this and other work the services of an organic chemist, to be classified as a "Senior Research Officer," are being sought.

Applications for several of the above vacancies close in the middle of August.

Alsifilm—A Substitute for Mica.

In the present troubled times, many nations are making strenuous efforts to produce within their own borders all the important or so-called "strategic" raw materials. The development of "alsifilm" in the United States of America as a substitute for mica is an interesting example of such efforts and of the far-reaching effects of scientific research.

Its unique combination of physical properties have made mica almost indispensable in certain of its uses, especially in the electrical industry. Although in some cases where the requirements are not too rigorous, mica has been replaced by micanite (small flakes of mica bonded together), alsifilm is the first substitute which can be used where high dielectric strength, particularly at high temperatures, is required. Small quantities of mica are mined in the United States, but the main supplies come from India, which not only has the largest mica mines in the world, but is one of the few countries where skilled labour is still cheap enough to permit splitting mica into thin films economically.

Alsifilm was developed in 1938 by Dr. Ernst A. Hauser, professor of chemistry at the Massachusetts Institute of Technology. The patents have been assigned to the Research Corporation, a body which puts back into research all profits accruing from its various enterprises.

This interesting product is made from bentonite, a colloidal clay with highly developed absorptive powers, which exists in important, easily worked deposits in the United States, notably in Wyoming, and in the Island of Ponza, in Italy. Of interest to mineralogists is the fact that although Wyoming bentonite was used in the original investigations and bentonites from other sources in later experiments, very similar results can be obtained with other clays and even with vanadium pentoxide sols. Clays of which 75 per cent. or more is in colloidal condition and which possess the property of rapid dispersion, have been found to be most suitable for the preparation of these films.

The technique of production of alsifilm is quite simple. The raw bentonite is dispersed in water, and the dispersion is allowed to settle or is centrifuged to remove the coarser particles. The colloidal material is either evaporated or concentrated in a super-centrifuge to the consistency of smooth paste which can be spread over a flat surface and then struck off to an even thickness by passing it under a knife. The moist film is next placed under a bank of incandescent electric lamps with infra-red reflectors, and films up to 4 to 5 thousandths of an inch thick are dried in this way in about five minutes; thicker films cause some difficulty. The final treatment is by immersion in a hardening bath, usually of lead acetate solution, which renders the material water-resistant. The sheets are now made separately in 3-ft. lengths and widths of 18 inches or more. Eventually, however, a continuous sheet may be produced and recovered in the form of a roll.

Aside from the fundamental laboratory research being carried out, quasi-commercial developments are now being conducted under co-operative arrangements with various companies. One of these companies is investigating the production of a cambric-type insulating tape impregnated with alsifilm; another is working on a combination of alsifilm with fiber glass, including both felted fibers and woven fabrics; and still other companies are directing their efforts to the production of substitutes for built-up mica sheet on board.

In addition to its use as a possible substitute for mica, alsifilm is being investigated as a substitute for paper, especially for permanent records. It takes ink well, can be strengthened by the addition of asbestos or other non-inflammable fiber, and may be opacified with a dispersed pigment. Other uses proposed are to line food or beverage containers and to wrap butter, tobacco, cigarettes, and other perishable or oily products.

The material may be modified in appearance and properties by incorporating various pigments and fillers. The product from ordinary Wyoming bentonite is not colourless, in fact, it looks like oiled paper. By using a white bentonite low in iron, however, almost perfectly transparent films are obtained.

The Research Corporation has issued a statement covering the present status of the product, in which they say there still remains the long step between the production of a small amount on a laboratory scale and large scale commercial production. Commercial development, looking towards the latter objective, is just starting, and hence it will be some time before the material will appear on the market in any quantity.

Fisheries Work in Western Australia.

The Government recently approved of the provision of £7,000 to cover the cost of construction of a second fisheries investigation vessel and £1,500 for the erection of a small biological station in Western Australia.

This decision follows a recommendation by the Council, after the Chief of the Fisheries Division, Dr. F. Thompson, had visited Western Australia and had submitted a report on his observations in that State. Prior to his visit, local authorities had repeatedly pointed out the desirability of carrying out some fisheries investigation work in western waters. In that connexion, the Division's existing vessel, the *Warreen*, could not be made available for some years on account of the claims on her in south-eastern waters.

Dr. Thompson reported that there are excellent potential bases at Albury, Bunbury, Geraldton, and elsewhere for prosecuting an active fishery industry in Western Australia, but that it would first be necessary to make a survey in the adjacent waters to determine the locations, movements, habits, and quantities of desirable fish. In conjunction with such investigations by a specially designed ship, it would be necessary to establish a small marine biological station.

Detailed plans for a second investigation vessel are now in the course of preparation by the Fisheries Division. It is proposed that the new boat will be a wooden Danish-seine netter of approximately 65 feet in length, diesel powered and equipped to test the demersal fisheries by Danish-seine netting, long line, and dredging (for shellfish), and the pelagic fisheries by trolling, live bait fishing, ring netting, and drifting.

The University of Western Australia is affording helpful co-operation in the proposed new work and has undertaken to staff and run the land biological station. Plans for this station, which it is proposed will be located near Fremantle, are now being prepared.

Lubrication and Bearings—Testing and Research.

The growth of the Australian aeroplane and engine industry will be assisted by investigations commenced recently by the Council for Scientific and Industrial Research into problems connected with lubrication and the construction of bearings. This work is being undertaken as a co-operative research with the University of Melbourne and is under the direction of Dr. F. P. Bowden, D.Sc. (Tas.), Ph.D., Sc.D. (Cantab.), Lecturer and Research Director in Physical Chemistry, Cambridge, and Fellow and Director of Studies in Natural Sciences at Gonville and Caius Colleges, Cambridge.

The Australian programme provides for a continuation of Dr. Bowden's previous studies carried out at Cambridge, and for the training of a research team in the highly specialized technique necessary for work in this field. This team consists of a chemist, an engineer,

and two physicists; it maintains close co-operation with the various University Departments concerned, as well as with Government Departments and private industry.

Results obtained from the Cambridge work have an important bearing on the practical problems of lubrication and wear, particularly on the lubrication of metals under difficult conditions of high temperature as, for example, in the case of piston rings and bearings of a modern high speed aero engine. They also provide a valuable guide in the selection of correct bearing metals for use under different practical conditions, and the prevention of corrosion, scoring, and seizure of bearings.

Although work was not started until January of this year, the major portion of the complex equipment required has been designed, constructed in the Engineering School, and set up in the new Chemistry School at the University. Preliminary investigations have included the development of a sensitive method for the estimation of the minute amounts of metals which accumulate in lubricating oils, measurements of the wear which occurs on vehicles driven on producer gas, and a study of the relative cutting and corrosive properties of imported and locally produced cutting oils. Other investigations include a study of the frictional properties and structure of bearing metals, and an examination of problems connected with the breakdown and seizure of bearings under conditions which resemble those obtaining during the high speed dive of an aeroplane.

Not only will these investigations be of value in the development of high speed aeroplane engines, but in the event of a shortage of lubricating oils they will enable substitutes to be rapidly tested and their suitability for various applications to be readily determined.

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Preparation of a Wood Sample for Chemical Analysis.

The Editor,

In an article by Dr. W. E. Cohen and Mr. A. W. Mackney recently published in this *Journal* under the above title, there occurs a statement which is somewhat misleading, and which may lead to misinterpretation of previous work (Campbell and Bryant, *Biochem. J.* **31**: 748, 1937) on the same subject.

The authors refer to an alleged claim put forward by Campbell and Bryant (*loc. cit.*) that there could be prepared from jarrah a 60–80 mesh fraction which would satisfactorily represent the whole of the wood when, in point of fact, no such claim was advanced. In the paper by Campbell and Bryant it is clearly stated that of the sawdust used

in their investigation the part which passed a standard 60-mesh screen was rejected and experimental work was confined to the remainder. The object of the work was to determine the effect of grinding and to obtain analytical data for the fractions of various particle sizes obtained after submitting sawdust to this type of comminution. Campbell and Bryant merely claim that the composition of the entire sample which they had under investigation (i.e., the wood which was ground) was best represented by the analytical data for the 60 80 mesh fraction. No attempt was made to relate the composition of the material investigated with that of the original sample of wood from which it was prepared.

W. A. ROBERTSON,
Director, Forest Products Research.

Reviews.

"Grassland Investigations in Australia."

(Herbage Publication Series, Bulletin 29, of the Imperial Bureau of Pastures and Forage Crops, Aberstwyth, Great Britain, 1940, pp. 108. Price 5s.)

This Bulletin forms an interesting survey of grassland investigations in Australia. An outline of the pasture research being carried out by the various institutions in Australia is followed by a series of fifteen special articles on different aspects of the work.

Pasture improvement seems feasible only on a comparatively limited proportion of the three million square miles of Australia, but where conditions are suitable there is much scope for improvement. This may be effected in four main ways: (*a*) the use of superphosphate and subterranean clover to raise the carrying capacity of the southern coastal pastures; (*b*) the sowing of pasture mixtures in districts with liberal rainfall; (*c*) improvements in methods of pasture management, use of rotational grazing, and conservation of fodder supplies; and (*d*) the recognition and selection of improved strains of pasture species.

The legume used most extensively for pasture improvement in the southern portion of Australia is subterranean clover, which is particularly valuable on leached soils which are low in fertility in their virgin state. In the main dairying areas where the wet season exceeds nine months of the year, white clover is used successfully in conjunction with rye-grass in the southern areas, and with paspalum on the eastern coast.

Pasture improvement in the semi-tropical and tropical coastal areas has been hampered because of the absence of a suitable legume. Rhodes grass grows successfully, but in the absence of a legume the swards deteriorate rapidly. An introduction of some promise is a perennial tropical legume (*Stylosanthes guyanensis*) from Brazil. This pasture plant has shown itself to be palatable, drought-resistant, and remarkably productive under favourable conditions.

In the dry pastoral areas where native plants form the chief pastures for stock, maintenance and regeneration are essential, and the prevention of deterioration of the plant cover by exploitative grazing is the most important phase of pasture research.

An example of the chemical aspect of pasture research is the investigation into the management of Sudan grass in an endeavour to reduce the danger of prussic acid poisoning. Weeds and insect pests, plant breeding and selection, northern and southern pastures, and the Australian environment in relation to grassland, are amongst the topics discussed in the Bulletin; 247 abstracts of the literature on grassland in Australia are also included.

"The Breeding of Herbage Plants in Scandinavia and Finland."

(Joint Publication No. 3 of the Imperial Agricultural Bureaux, 1940, pp. 125. Price 4s.)

Arrangements have been made between the various Imperial Agricultural Bureaux whereby any publication upon the preparation of which two or more Bureaux collaborate shall be included in a new series entitled Joint Publications. It has been decided to regard the earlier Joint Publications on "Vernalization and phasic development of plants" and "Erosion and soil conservation", as Nos. 1 and 2 in this series. Other Joint Publications produced in recent years but already out of print have not been given numbers in the series.

The Imperial Bureau of Plant Breeding and Genetics and the Imperial Bureau of Pastures and Forage Crops have now produced Joint Publication No. 3, entitled "The breeding of herbage plants in Scandinavia and Finland". It is a symposium consisting of a series of articles by acknowledged specialists in the respective countries. G. Nilsson-Leissner, F. Nilsson, E. Akerberg, and R. Torssell contribute articles on work in Sweden, H. N. Frandsen, H. Wexelsen, and O. Pohjakallio on Denmark, Norway, and Finland respectively.

Each article reviews recent developments in the countries concerned, including details of the most recent improved strains of grasses, clovers, and lucerne, and the methods used in producing them, as well as a contribution on the application of cytology to herbage plant breeding. The articles vary from 5 to 35 pages in length and are mostly quite detailed, each being provided with a mass of tabular data and selected bibliographies. The Scandinavian countries are recognized authorities on grassland and breeding problems, and the bulletin provides an invaluable outline of achievements up to date. This is made specially clear by a useful summary of the entire contents of the bulletin which appears at the beginning, before the presentation of the individual articles. Another useful feature is the provision of a list of addresses of the research stations concerned and of maps illustrating their locality.

The bulletin covers some 125 pages and is obtainable from either Bureau at the moderate price of 4s. Standing orders for Joint Publications should be placed with the Secretary, Imperial Agricultural Bureaux, 2 Queen Anne's Gate Buildings, London, S.W.1.

Conditioning of Blowfly Insectary—Grant from Australian Wool Board.

The insectary used by the Council's Division of Economic Entomology at Canberra for testing, on living sheep, the efficacy of various fly-strike dressings, repellents, jetting fluids, &c., is, in effect, merely a flyproof enclosure. In consequence, it is possible, in the Canberra climate, to use it only during the warmer five months of the year for the particular tests in question.

For some time past it has been felt that it would be desirable to have the necessary alterations made to the insectary in order that the inside temperature might not be allowed to fall below 50 deg. F., as in that way tests on dressings could be carried out right throughout the year.

The Australian Wool Board has now made the Council a grant of £400 to cover the necessary capital expenditure involved in the heat conditioning of the insectary in this way. Plans for the necessary alterations have been prepared, and it is expected that the work will be put in hand at an early date.

Work on Dried Fruits—Grant from Commonwealth Dried Fruits Control Board.

For a number of years past, the Commonwealth Dried Fruits Control Board has been making a very substantial contribution of £1,500 towards the work of the Council's Irrigation Research Station at Merbein, Victoria. The work of this Station is directed mainly towards problems associated with the production, processing, and preservation of dried vine fruits, and the irrigation, soil preservation, and soil reclamation of the Murray River Settlements in which these dried fruits are produced. The total expenditure of the Station is upwards of £9,000 per annum.

Advice has just been received from the Board that it has again decided to support the Station for the financial year 1940-41. With that end in view, despite difficulties involved in disposing of the export surplus of dried fruits in the various overseas markets, it has decided to contribute its usual £1,500 per annum for the year in question.

Recent Publications of the Council.

Since the last issue of this *Journal*, the following publications of the Council have been issued:—

Pamphlet No. 96.—"Further Investigations on Copper Deficiency in Plants in South Australia," by D. S. Riceman, B.Ag.Sc., C. M. Donald, B.Sc.Agr., and S. T. Evans, B.Sc.

After finding that coast disease of sheep was caused by deficiency of copper and cobalt in the soil, the Council turned its attention to the effect of these deficiencies on plants in the area. The present pamphlet is the second of a series dealing with the investigation.

Previously, attempts to establish permanent pasture legumes and grasses in affected areas had failed, and rye was the only cereal crop which could be grown profitably. It has now been shown that application of copper sulphate enables oats, wheat, and the better types of pasture species to be successfully grown. Maximum yields of oats and wheat were obtained when copper sulphate was applied at the rate of 14 to 56 lb. per acre.

Affected soils are composed of fine marine shell fragments blown by the prevailing winds into gently rolling dunes. It is thought that they may also be deficient in other minerals necessary for plant growth, and this is being investigated. In pot experiments, subterranean clover showed marked response to addition of iron as well as copper to the soil. Different varieties of the one plant often show considerable variation in resistance to copper-deficient conditions. *Avena strigosa* has shown itself to be a very resistant species of oats, and, if it is able to compare in this respect with rye under field conditions, it should be a more satisfactory hay crop.

Investigations on pastures are necessarily of longer duration than those with cereals, but a vigorous pasture of black medic and Wimmera rye-grass has been established by the use of copper sulphate.

Pamphlet No. 97.—"The Shrinkage of Australian Timbers. 2.—Shrinkage Data for 170 Timbers," by W. L. Greenhill, M.E., Dip.Sc.

This pamphlet gives shrinkage values for 170 Australian timbers in a form in which they can readily be used commercially. The previous pamphlet on the subject paid most attention to the theoretical aspect of timber shrinkage. The publication should be particularly useful at this time, as it will be a guide in many cases where imported timbers must be replaced by Australian woods to save dollar currency.

Although many and varied attempts have been made to eliminate or reduce the changes in dimensions which wood undergoes with change in moisture content, these have met with but limited success as far as their general application is concerned. Shrinkage during drying, and its attendant troubles of checking and warping and the "working" of dry wood with atmospheric changes, continue to be perhaps the greatest problems in timber utilization, and reliable information regarding the behaviour of different timbers in this regard is of very considerable importance. For certain purposes, it is necessary to use timbers in which the amount of shrinkage or swelling is as small as possible. Reference to the tables given in the pamphlet will allow of such a selection, which can be further narrowed down after a consideration of the other desirable properties such as density and ease of working.

Pamphlet No. 98.—"The Prevention and Treatment of Blowfly Strike in Sheep," Report No. 2 by the Joint Blowfly Committee.

The Joint Blowfly Committee co-ordinates the sheep blowfly research undertaken by the Council and the New South Wales Department of Agriculture. The report is in the nature of a practical handbook and is being distributed mainly by the various State Departments of Agriculture.

The pamphlet deals with the practical measures that can be applied to reduce the inherent disposition of sheep to blowfly strike, and the methods to reduce the immediate susceptibility that may develop. Measures that may be used to reduce the population numbers of the sheep blowfly, and finally the methods of treating strike, are also dealt with. It is pointed out that sheep growing the necessary quantity and quality of wool, but with a low predisposition to fly strikes, can be evolved by selective breeding. The Mules operation is described in detail and recommended as a method of making predisposed sheep less susceptible to fly strike. The most modern methods of protecting sheep by jetting with calcium arsenite are also outlined. It is recommended that strikes should be treated with soothing, non-irritating dressings containing a substance toxic to the fly maggot. Boracic acid is harmless to the sheep but very toxic to the maggot.

Pamphlet No. 99.—"Studies on Chemical Weed-killers with Special Reference to Skeleton Weed," by C. G. Greenham, M.Sc., G. A. Currie, D.Sc., B.Agr.Sc., and F. E. Allan, M.A.

This pamphlet consists of three papers. The first discusses the physiology of skeleton weed in relation to its control by herbicides. It is shown that the most favourable growth stage at which to spray is that just prior to the dying off of the rosette leaves, provided that the soil is then low in moisture content.

The second paper outlines a method for comparing the toxicity of translocated sprays. The method is applicable to tap-rooted plants, and uses as its criterion the length of the subterranean axis killed.

The third paper discusses the relation of the time of the day at which an acid-arsenical spray is applied, to the efficiency of kill of skeleton weed. In the experiment, the most effective applications were made during the period 3.15 p.m. to 1.15 a.m., with maximum efficiency at 5.15 p.m.

Forthcoming Publications of the Council.

At the present time, the following future publications of the Council are in the press:—

Bulletin No. 133.—"A Soil Survey of the Mildura Irrigation Settlement, Victoria," by F. Penman, M.Sc., G. D. Hubble, B.Agr.Sc., J. K. Taylor, B.A., M.Sc., and P. D. Hooper.

Bulletin No. .—"Investigations on the Storage of Jonathan Apples grown in Victoria," by S. A. Trout, M.Sc., Ph.D., G. B. Tindale, B.Sc.Agr., and F. E. Huelin, B.Sc., Ph.D.

Bulletin No. .—"Studies on Bovine Mastitis. 1.—Study of an Experimental Herd," by L. B. Bull, D.V.Sc., D. Murnane, B.V.Sc., E. Munch-Petersen, M.Sc., Ph.B., M.I.F., Jean D. MacLean, B.Sc., and S. E. R. Clark, B.Agr.Sc.

Bulletin No. .—"Experimental Studies of Ephemeral Fever in Australian Cattle," by I. M. Mackerras, B.Sc., M.B., Ch.M., and M. J. Mackerras, M.Sc., M.B.

Pamphlet No. 100.—"Studies on the Marketing of Fresh Fish in Eastern Australia. Part 2.—The Bacteriology of Spoilage of Marine Fish," by E. J. Ferguson Wood, M.Sc., B.A., A.A.C.I.

Pamphlet No. 101.—"Studies of the Physiology and Toxicology of Blowflies. 2.—The Action of Stomach Larvicides of *Lucilia cuprina,*" by F. G. Lennox, M.Sc., A.I.C. 3.—"The Toxicity of Some Arsenicals to Larvae of *Lucilia cuprina,*" by F. G. Lennox, M.Sc., A.I.C., and L. G. Webber. 4.—"The Action of Contact Larvicides on *Lucilia cuprina,*" by F. G. Lennox, M.Sc., A.I.C.

Pamphlet No. 102.—"Studies of the Physiology and Toxicology of Blowflies. 5.—The Hydrogen Ion Concentration in the Alimentary Canal," by D. F. Waterhouse, M.Sc. 6.—"The Absorption and Distribution of Iron," by D. F. Waterhouse, M.Sc. 7.—"A Quantitative Examination of the Iron Content of *Lucilia cuprina,*" by F. G. Lennox, M.Sc., A.I.C.

Fisheries Circular No. 1.—"Some Notes on the Smoking of Fish," by E. J. Ferguson Wood, B.A., M.Sc., A.A.C.I.

Fisheries Circular No. 2.—"The Canning of Fish and Fish Products in Australia," by E. J. Ferguson Wood, B.A., M.Sc., A.A.C.I.

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